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OF THE

REGENTS

1896

VOL. 2

REPORT OF STATE GEOLOGIST AND FIELD ASSISTANTS

ALBANY
UNIVERSITY OF THE STATE OF NEW YORK
1899

University of the State of New York

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REPORT.

Office of the State Geologist,

Room 32, State Hall,

Albany, N. Y., *April 20, 1897.*

To His Excellency Frank S. Black, *Governor of the State of New York:*

Sir: — I have the honor to transmit herewith the annual report of the State Geologist for the year 1896, embracing an account of field and office work for the past year.

The completion of the geologic map has been one of the principal objects to which the field work has been directed, as will be evidenced in portions of the state which have been covered during the past year.

The report on the geology of the salt, and the salt districts of New York by Mr. D. D. Luther, which accompanies this report, completes the work in that direction. This final report, together with that upon the economic resources of Onondaga county, published in my last report, will be a useful and valuable work of reference, especially for persons engaged in the salt industry and for the entire people of the state. In completing the field work on the geology of this part of the state, Mr. Luther has occupied considerable time in the study and collection of materials along the valleys of the Genesee river and the Tonawanda creek, in order to determine the limits of the "*Portage group*," of the final reports of the geological survey, and the relation of this formation to the rocks above and below. The results of this work will be transmitted with my next report.

Prof. Charles S. Prosser of Union College has continued his work in the central portion of the state upon the Hamilton, Portage and Chemung groups, the results of which will be a valuable contribution to our knowledge of the limits and distribution of these formations and their contained faunas.

In the northern part of the state, Prof. H. P. Cushing has been working upon the boundary line between the crystalline rocks of the Adirondacks, and the Potsdam sandstone to the north. This work has been completed across

the counties of Clinton and Franklin, and to some extent within the limits of St. Lawrence county. The work of the present season which will be continued by Mr. Cushing will complete the knowledge of the geology of that portion of country preparatory to its final adoption upon the geologic map.

Those portions of the published map which were left blank in Oneida, Jefferson and Oswego counties have been carefully examined by Mr. C. J. Sarle, who has travelled on foot over the boundary line of the crystalline rocks to the Calciferous sandstone and the succeeding limestones, including the Trenton. He has also examined in the same manner the belt of country along the upper limits of the Trenton limestone and the contact of that formation with the Hudson river shales.

Mr. A. W. Grabau, of the Massachusetts Institute of Technology, has contributed a paper upon the fauna of the Hamilton group at Eighteen-mile creek on Lake Erie, and since this paper contains some interesting data in regard to the geology and palæontology of that part of the state, it has been adopted in this report, as a contribution to our knowledge.

Prof. J. M. Clarke, assistant state geologist, has contributed an important paper upon the fauna of the Goniatites intumescens zone of the Portage group. This paper is the result of much work in the collection of material in the field, and of office study, and will be an interesting contribution to our knowledge of this fauna and its geologic relations.

A description of the fossil corals, which have been under investigation for many years, and for the illustration of which a large number of drawings have already been made, will constitute a portion of a following report.

The Memoir upon the Dictyospongidæ, commenced in the report of last year, will be continued in this report; completing the work with about seventy plates and more than two hundred pages of text.

Very respectfully, your obedient servant,

JAMES HALL,
State Geologist and Palæontologist.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.
(GEOLOGICAL MAP.)

REPORT ON THE BOUNDARY BETWEEN THE POTSDAM AND PRE-CAMBRIAN ROCKS NORTH OF THE ADIRONDACKS.

JAMES HALL,
State Geologist.

H. P. CUSHING,
Special Assistant.

1896.

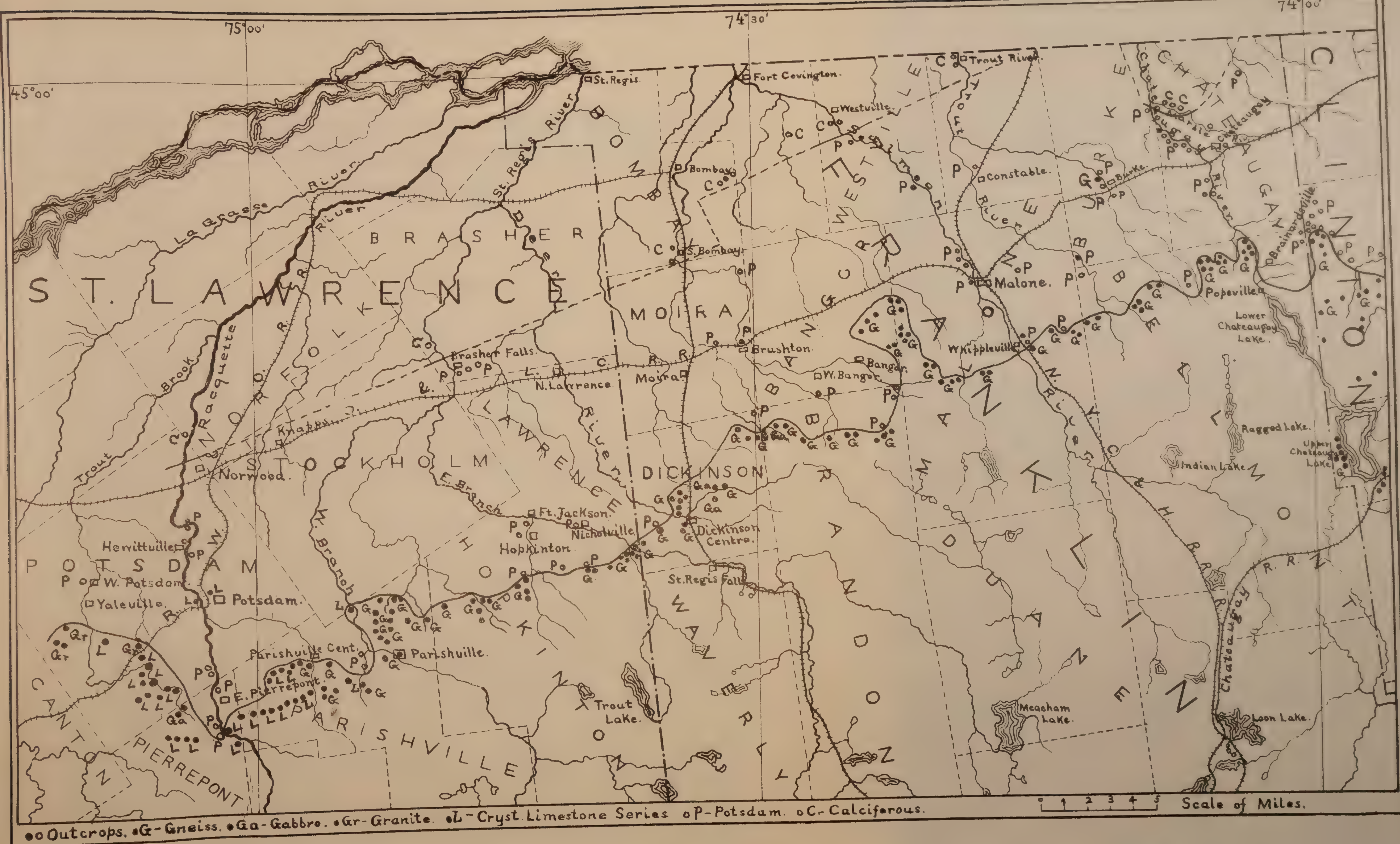
James Hall, *State Geologist.*

Sir:—The accompanying report is made in accordance with your instructions to map the northern boundary between the Potsdam sandstone and the Pre-cambrian crystallines across Franklin county and as far into St. Lawrence county as practicable; further, to determine what rocks younger than the Potsdam come in on the north and their limits, and, in addition, to make observations on the change in the character of the gneisses in going westward.

Respectfully yours,

H. P. CUSHING.

March, 1897.


75°00'
74°30'
74°00'
45°00'
ST. LAWRENCE
FRANKLIN
BRASHER
NORFOLK
STOCKHOLM
LAWRENCE
MOIRA
BOMBAY
WESTVILLE
BANGOR
MALONE
BURKE
CHATEAUGAY
DICKINSON
POTSDAM
HOPKINTON
PARISHVILLE
CANTON
PIERREPONT
WAVERLY
BRANDON
DUANE
CONSTABLE
BELLMONT
St. Regis.
Fort Covington.
Trout River
Westville.
Bombay
S. Bombay
Constable.
Burke
Malone.
Popeville
Brushton.
Bangor.
W. Bangor.
Whippleville
Brasher Falls.
N. Lawrence.
Moira
Norwood.
Knapps
Ft. Jackson.
Nicholville.
Hopkinton.
Dickinson Centre.
St. Regis Falls.
Hewittville
W. Potsdam
Yaleville.
Potsdam.
Parishville Cent.
Parishville.
E. Pierrepont.
Trout Lake.
Meacham Lake.
Loon Lake.
Indian Lake.
Ragged Lake.
Upper Chateaugay Lake.
Lower Chateaugay Lake.
La Grasse River
Racquette River
St. Regis River
Deer River
Trout Brook
Trout River
Chateaugay River
Salmon River
E. Branch
W. Branch
Brainardsville
Scale of Miles.
0 1 2 3 4 5
Outcrops. G - Gneiss. Ga - Gabbro. Gr - Granite. L - Cryst. Limestone Series P - Potsdam. C - Calciferous.

REPORT ON THE BOUNDARY BETWEEN THE POTSDAM AND PRE-CAMBRIAN ROCKS NORTH OF THE ADIRONDACKS.

By H. P. Cushing.

Introduction.

The work of tracing this boundary was begun at the Clinton-Franklin line, connecting with the writer's work of the previous season. Thence the boundary was mapped across Franklin county and into St. Lawrence to a few miles west of Potsdam. It was not known to me until after my return from the field that part of the area traversed in the latter county had already been studied and reported upon by Professor Smyth. As the report has not, at this writing, been published, what follows must unfortunately be written without reference to it.

The country north of the Adirondacks is so heavily covered with drift that outcrops of the Palaeozoic rocks are very infrequent and boundary mapping is rendered hazardous on that account. Over much of the distance the best that could be done was to map the northerly limit of Pre-cambrian outcrops. In Franklin county and as far west as Parishville in St. Lawrence county, the mapping was a simple matter. The gneisses are so similar in

character and in resistance to erosion that the boundary is not especially tortuous, and though it is quite possible that isolated patches of the Potsdam may occur within the gneissic area, as has been found to be the case in Essex and Clinton counties, their discovery would require the mapping of a much larger area.

Westward from Parishville, the Pre-cambrian rocks at the boundary consist of an entirely different series of gneisses with belts of crystalline limestone. These rocks resist erosion very unequally, and as a whole are less resistant than those along the boundary to the eastward. The change in the topography, which is there strongly marked, is here much less serviceable. Furthermore these rocks were profoundly and unequally eroded in pre-Potsdam time. In the troughs thus formed the Potsdam sandstone was deposited and is yet found in them far within the area occupied by the older rocks.* To fix accurately the limits of the formations here will require areal mapping over an extended territory.

No rock of younger age than the Calciferous was found in the district examined, the Pleistocene deposits of course excepted. Outcrops occur so seldom that it is useless to attempt to show the limits of the formation except in the most general way.

On the map accompanying this report these boundaries are indicated, and the various outcrops seen are located. It must be borne in mind that the small scale of the map makes the outcrops appear much more numerous than is really the case.

TOPOGRAPHY.

In a broad sense the topography of the district under consideration is simple. The Pre-cambrian rocks come to the boundary in a succession of low ridges and knobs which ordinarily do not protrude very greatly above the general level, and which are separated by shallow, drift-filled depressions. Thence northward the country is heavily mantled with drift, has little relief, and slopes away to the north and north-west toward the St. Lawrence valley. Only rarely does the underlying rock project above the drift, the small streams do not cut through it, and in general the only outcrops to be seen are those exposed in the larger streams where they are out of their pre-glacial channels.

The minor features of relief which characterize districts of morainic drift (and much of it here is morainic) are here obliterated over much of the district, more especially along the stream valleys, by the deposits of sand laid down

* By way of illustration see Smyth's map of the vicinity of Gouverneur. Rep. N. Y. State Geol., 1893, Vol. I, p. 493.

upon it along the streams or the shores of the higher water levels which accompanied and followed after the withdrawal of the ice-sheet from northern New York.

The water-shed between the lake Champlain drainage and that direct to the St. Lawrence, passes from north to south through Clinton county close to the Franklin county line, till it veers to the south-westward into Franklin county just south of Upper Chateaugay lake. On this watershed the basal Potsdam reaches an altitude of about 1100′ A. T. Thence westward along the boundary it decreases steadily until south of Potsdam city it lies at an altitude of from 700′ to 800′ lower. This discrepancy must necessarily be due to differential uplifting since its deposition.

The largest streams, like the Racquette, St. Regis, Salmon and Chateaugay rivers flow in narrow valleys cut in the drift, and in still narrower rock gorges where they are out of their old channels. They are all actively engaged in deepening their channels and cutting back the rapids at the head of the gorges. The gorge of the Chateaugay is, in impressiveness, second only to the Ausable Chasm in the Adirondack region. The more westerly streams have less fall and are not cutting so actively.

THE GLACIAL DEPOSITS.

Only general attention could be given to the drift deposits, so that the hap-hazard observations made would not be commented on, were it not for the fact that the deposits are of great interest and are but little known.

Over a wide area north of the Adirondacks the drift proper is submerged beneath heavy sand deposits, the conditions being very similar to those prevailing in Clinton county near lake Champlain. The sands are of course mainly along the stream valleys but have considerable width on each side and become confluent when the streams are not far apart. Morainic knobs and ridges protrude through them here and there and cuts often show the underlying drift. The north and south roads in northern Franklin county and the adjacent part of St. Lawrence county are commonly near enough to some stream to make the roads excessively sandy, and driving over them is a most irksome task. The cross roads pass over the divides between the streams and are better.

These sands are found abundantly at certainly three, and probably four distinct levels and the descent from one level to another is sometimes quite abrupt, the sand plains rising in terraces, one above another. This is well shown just north of Malone, where the sand plain stretching north from the

city terminates like a huge embankment, dropping nearly 100′ to a similar sand plain below. The lower sands certainly represent delta deposits of the streams in bodies of standing water. Whether that is true of the uppermost is not so certain. What were apparently true beaches were noted at three or four points, but no attempt to trace them could be made. These sand-covered tracts are very level, and quite bare of vegetation, the sand often drifting to a considerable extent.

Outside of the sand-covered areas the surface drift is largely morainic in character. In many places heavy moraines lie in proximity to, or banked up against the out-lying gneiss ridges. Surface boulders are numerous over most of the district, and their extremely local character is worthy of remark and is most strikingly shown along the line of contact between the Potsdam sandstone and the Calciferous.

In passing north from the outermost outcrops of gneiss in Bangor, Brandon and Dickinson townships, Franklin county, one descends often into a slight depression, then rises on to a morainic ridge with boulders mainly of very large and sometimes of gigantic size, composed entirely of gneisses precisely similar to those in place to the south. Practically no Potsdam boulders are observable. The ridge is not entirely morainic, being composed in part of modified drift. It has a variable width, reaching sometimes half a mile. To the north of it, with an intervening depression is a much more massive moraine whose boulders are of smaller size, and are mainly of Potsdam sandstone, while the few gneissic boulders observable are of small size and, when compared with the blocks on the other moraine are more worn and give the impression of having traveled much further. The facts observed suggest that the smaller moraine may have been formed by a local ice movement outward from the Adirondack center after the withdrawal of the main ice sheet. While they are far from being conclusive they certainly suggest an interesting line of inquiry. Such a movement is perhaps *a priori* to be expected and Prof. C. H. Hitchcock has shown that a similar one took place from the White mountains center after the withdrawal of the Laurentide glacier.

SEQUENCE OF GEOLOGIC EVENTS IN THE ADIRONDACKS.*

1. The oldest rocks, and also the most widespread of the region, comprise a series of gneisses of somewhat variable character and questionable origin. Owing to profound metamorphism all trace of original structure is lost, their

*This summary of the geologic history of the region is intended merely to set forth the writer's present views concerning that history, and is of course merely tentative, as work is really but fairly begun. These views, it is thought, are in substantial accord with those held by Profs. Kemp and Smyth, and the history is closely paralleled by that of the Canadian area lying to the northward, as set forth by Prof. F. D. Adams.

present structure being predominantly cataclastic, though this structure is often masked by a greater or less amount of subsequent re-crystallization. They vary from well foliated rocks to those in which all trace of this structure has well nigh disappeared. In texture they vary from very finely granular rocks to very coarse varieties. They abound in quartz and pegmatite veins. According to their mineralogic composition they may be roughly classified in three groups.

(*a*) Quite acid gneisses, poorly foliated, commonly of red color, mostly poor in content of ferro-magnesian silicates, and with the mineralogy and composition of granites. They consist essentially of microperthitic orthoclase and quartz, with magnetite always present, and with an acid plagioclase, microcline, hornblende, biotite, apatite, zircon, and rarely garnet as accessory minerals. A strongly absorptive green-brown hornblende is the usual dark silicate and becomes a prominent constituent in portions of the gneiss. Biotite is an exceptional mineral in these gneisses and even when present is always subordinate to the hornblende, biotite gneisses being of extreme rarity in the rocks of this group in the northern Adirondacks at least.

(*b*) Gneisses whose main difference from those just described consists in the predominance of microcline among the feldspars. In the field they are often undistinguishable from the other gneisses. At other times owing to their fineness of grain and their peculiar lilac grey or lilac brown shade on fresh fracture, they appear quite distinct. They are so intimately associated with, and pass so gradually into the other type that the wisdom of attempting to distinguish them is by no means beyond question. They commonly occur in proximity to, and may belong with the Grenville series.

(*c*) Gneisses composed essentially of orthoclase, acid plagioclase and augite, with accessory titanite, hornblende, apatite, magnetite and ilmenite, quartz, garnet and biotite, in order of prominence. In composition they grade from augite-syenites into gabbroic rocks, or from hornblende-syenites into dioritic rocks according to the relative predominance of orthoclase or plagioclase. The more basic varieties, however, are more acid than the normal gabbros of the region, their feldspars belonging to the oligoclase-andesine series, seldom if ever becoming as basic as labradorite. The augites in these rocks are very variable in character, ranging from a light-green, non-pleochroic diopside to pleochroic varieties resembling aegerine-augite. The titanite is of a deep orange color and is so constant and characteristic as to almost attain the dignity of an essential constituent. Hornblende varies from complete absence to

an amount considerably in excess of that of the pyroxene. Much of the quartz present exists as inclusions in the feldspar and hornblende.

These gneisses are much more distinctly foliated than the other varieties, due to the concentration of their dark silicates along the planes of foliation. They pass into the others either by insensible gradation or by becoming finely interbanded with them. They also seem to grade into the basic gabbros of the region; at least these latter present phases practically not to be distinguished from them. The possible relationship between the two forms is one of the most pressing and puzzling problems here presented for solution.

The gneiss series is thought to be of igneous origin and in part, at least, of Archaean age, in the sense in which that term is used by the U. S. Geological Survey. There are, however, certain difficulties in the way of this view.

The magnetite deposits of the region are in this series, and, in large part at least, in the augite-gneisses, the deposits at Mineville, Essex county, according to Kemp, being in such rocks, as are also those of Lyon mountain and of Arnold and Palmer hills in Clinton county.

II. *The Grenville (Oswegatchie) Series.* The term "Oswegatchie series" was proposed by Smyth to include the coarsely crystalline limestones and associated rocks as exposed in St. Lawrence, Lewis and Jefferson counties.* In the writer's opinion these rocks are so similar to those of the typical Grenville series of Logan, and are separated from them by such a comparatively slight geographic distance that that term might with perfect propriety be utilized for the New York rocks.

This series is very heterogeneous in character. It comprises quartzose gneisses and schists, darker colored quartz-feldspar-biotite gneisses, dioritic and gabbroic gneisses, and occssional bands of coarsely crystalline limestone. Graphite is an abundant mineral. Pyrite is another, aiding by its decomposition in the production of the rusty, decomposed aspect which some of the beds present in outcrop. Sillimanite and tremolite are frequently present as is also garnet. The rocks are cut by later gabbros and granites, and are accompanied by belts of gneiss similar to the older gneiss, which seem at times to be interstratified with the other rocks, but concerning whose real relationships we are in doubt.

For the most part the gneisses of this series differ widely in appearance from the older gneisses, and may be distinguished from them in the field almost at a glance. A considerable portion seems to be unquestionably of

* C. H. Smyth, Jr., Rep. St[illegible] eologist, N. Y., 1893. Vol. I, p. 496.

sedimentary origin, yet has been so profoundly modified that practically all trace of clastic structure has disappeared. The larger part of the rocks have a very finely granulitic structure, having undergone nearly complete re-crystallization. The dynamic metamorphism to which they have been subjected has given them a foliation in common with the older gneisses, rendering the field relations of the two exceedingly obscure.

From Parishville westward to Potsdam and beyond, the Grenville series comes to the Potsdam boundary and may be seen to great advantage. Here, on the western side of the Adirondacks, it differs somewhat in character from the similar rocks to the eastward, being more widely distributed, less faulted, less completely metamorphosed, hence with its original sedimentary character less disguised. The distance from the great anorthosite intrusion, which has so profoundly affected these rocks on the east, is a probable cause for these differences.

That the eastern and western representatives are equivalent seems to be beyond question. It is, however, quite desirable that they should be connected by tracing them across Franklin county.

III. *The Anorthosite Intrusion.* At some time after the deposition of the rocks of the Grenville series, a great batholitic mass of the highly feldspathic variety of gabbro known as anorthosite was intruded into the existing rocks. The structure of the gabbro indicates that it solidified at considerable depth, hence the rocks with which it is now in contact must have been buried beneath other rocks, since wholly removed by erosion. The anorthosite has its largest development in Essex county. In Clinton county it is exposed around Keeseville and on Catamount mountain and Rand's hill. It occurs in the eastern part of Franklin county but its extent is not known. Further westward its presence is problematical.

IV. *Later Gabbros.* Dark colored rocks of the gabbro family, of greater basicity than the anorthosites, occur wide-spread in the Adirondack region, extending far beyond the limits of the anorthosites. They occur most frequently in the form of dikes or sheets of no very great width, though larger masses are not uncommon. In part they are certainly later than the anorthosites, for they cut them. They may in part represent apophysae from them, and basic peripheral portions of the intrusion, though this has not yet been demonstrated. The gabbro at Port Henry has been described in detail by Kemp,* and some occurrences from the western Adirondacks described by

* J. F. Kemp, Bull. G. S. A., Vol. V., pp. 213–224.

Smyth.* Similar gabbros have an extended distribution among the older rocks to the south and west.

The wide mineralogic variations commonly exhibited by these rocks find excellent illustration here, the typical gabbros grading into diorites on the one hand, and into norites on the other. All are more or less foliated, the hornblendic varieties most markedly so.

Along with these rocks may well be included the narrow, dike-like bands of hornblende-plagioclase gneiss found everywhere cutting the older gneisses of the region, and which apparently represent ancient diabase or diorite dikes.

V. *Granite.* Granitic rocks are frequent in the Adirondacks. In part they represent merely granitic phases of the basal gneisses, but in part they are of later date. The writer has frequently found in the northern Adirondacks, granites which cut across the gneisses, and Smyth has described an occurrence from St. Lawrence county with irruptive contact against Grenville limestone.† Evidence of the time relation between the granite and the gabbros is not at hand, though Smyth has described a contact where he believes the latter to be the younger.‡

The granite is commonly of red color, well jointed, unlike the gneisses, and composed essentially of quartz, orthoclase, microcline and oligoclase, ferromagnesian silicates being absent, or at best only sparingly present.

VI. *Dynamic Metamorphism of the Region.* After the time of these various igneous intrusions the region was subjected to intense dynamic metamorphism, whereby secondary structures were produced and the primary ones destroyed; the rocks were all rendered thoroughly crystalline and their original relationships masked. That the rocks now exposed at the surface were then deeply buried beneath other rocks, since removed by erosion, is shown by the manner in which the rocks adjusted themselves to the forces acting upon them, the adjustments being of the kind that can only occur under heavy load.

VII. *Pre-cambrian Dikes.* At some period subsequent to the metamorphism of the region, all the rocks so far described were fissured, and through the fissures thus formed fused rock made its way toward the surface. Along some of these fissures faulting took place. That earth movements produced results of this character leads to the belief that the rocks were under

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*C. H. Smyth, Jr., Bull. G. S. A., Vol. VI, pp. 263-274. Also, Am. Jour. Sci., Vol. XLVIII, pp. 54-65 and Vol. L, pp. 273-281.

†C. H. Smyth, Jr. Bull. G. S. A., Vol. VI, p. 266.

‡C. H. Smyth, Jr. Bull. G. S. A., Vol. VI, p. 270.

less load than at the time of their great metamorphism, and thus a long intervening erosion period is suggested.

The erupted rock may or may not have reached the surface. So far as known it is found at the present day solely in dikes. These are exceedingly abundant in the eastern Adirondacks. Though presenting considerable variation they may all be classed as diabases, and mostly as olivine diabases.

Accompanying these dikes, and having, so far as observed, the same area distribution though far less abundant, are other dikes, ordinarily of red color, of a much more acid rock. The writer has heretofore classed these with the trachytes (bostonites), but they present constant differences when compared with the lake Champlain bostonites, and evidence is accumulating that they are distinct in age. They are quite numerous in Clinton county and in the eastern part of Franklin, and have not been seen cutting any but the Pre-cambrian rocks. While they may be nothing but representatives of the post-Utica trachytes the writer is disposed provisionally to regard them as distinct, and of Pre-cambrian age. They have the same general east and west trend as the diabases, and neither has as yet been observed cutting the other.

VIII. *Palaeozoic Rocks.* After this period of dike formation, erosion continued in progress for a considerable length of time. Then ensued a depression carrying all the peripheral portion of the Adirondack region below sea level, where it remained during the deposition of the Potsdam sandstone and the lower Silurian limestones, which were laid down on the deeply denuded but uneven floor of the older rocks.

The Potsdam sandstone north of the Adirondacks is of very considerable, though unknown thickness. It is at least as much as 500′ however, and probably considerably more. From the lack of fossils except in the upper portion it is an extremely difficult formation to subdivide. The extreme basal portion is a conglomerate, often very coarse, and also carries layers of coarse, feldspathic and hematitic, easily rotting sandstone. Otherwise it is a quite pure quartz sandstone, though occasionally some layers are dolomitic. The basal one-fourth is prevailingly of red color, while the remainder is white, yellow or brown. It grades into the Calciferous dolomites above through passage beds, 30′ to 50′ thick, of alternating layers of sandstone and grey dolomite. In its upper portion it carries an upper Cambrian fauna.

IX. *Post-Utica Uplift.* After the close of the lower Silurian the submerged district was raised anew above sea level and was then affected by the earth movements which caused the Green mountain uplift. But whereas the rocks of Vermont were folded, faulted and metamorphosed by their action, the

effect produced in New York was much less pronounced and mainly effective in the production of faults, the rocks being only slightly folded and not metamorphosed at all. The faults, however, are very numerous and often of considerable magnitude. The present topography is largely due to their presence and they have no doubt frequently served as lines of readjustment since they were originally formed.

X. *Post-Utica Dikes.* During or subsequent to the time of the dynamic movements just referred to, igneous rocks made their way toward the surface through fissures. They are now found mainly as dikes and, as shown by Kemp, are of two widely different types, both very basic rocks (camptonites, monchiquites, fourchites) and quite acid rocks (trachytes) occurring. The basicity of the one type and the acidity of the other seem somewhat more pronounced than in the case of the supposed Pre-cambrian basic and acid dikes. As far as New York state is concerned, these dikes seem confined to the vicinity of lake Champlain, not ranging westward as do the earlier dikes.

FAULTS.

The true boundary, if its minutiae could be mapped on a large scale, would necessarily be exceedingly irregular. The Potsdam was laid down on an uneven floor, especially so when the Grenville series formed that floor, and where it has been pared away by erosion down to its very base this irregularity of floor must make a highly tortuous contact line. These minor details are for the most part obscured by the drift covering. An interesting illustration is furnished by exposures two miles south of Nicholville, St. Lawrence county, which will be described in their appropriate place.*

While some of the contacts are clearly those of deposition others are unquestionably due to faulting. The much-faulted structure of the eastern Adirondacks has been emphasized in previous reports by Professor Kemp and the writer. In the district under consideration here, the evidence is less pronounced, but that faults are present, and that numerously, is clear. The well known outcrops of Potsdam sandstone along the Racquette river south of Potsdam lie along the west side of a fault. The outlier of gneiss at Burke village, Franklin county, seems brought up by a pair of faults. Two miles northeast of Whippleville, Malone township, are Potsdam exposures whose attitude is due to faulting.

*The areal results of the work are delineated, so far as may be, on the accompanying map. As outcrops of the Potsdam sandstone are very infrequent much of the boundary as there shown can only be regarded as a reasonable approximation, it being marked at the limits reached by the Pre-cambrian outcrops, with such aid as the topography furnishes. Westward from Parishville its true position is quite uncertain, the conditions being much more complicated than those prevailing to the eastward.

While the great scarcity of exposures of the Calciferous dolomites renders hazardous any attempt to delineate the Potsdam-Calciferous boundary and to generalize concerning structural relations, the prolongation of the north-easterly strike invariably shown in outcrop would not connect the different exposures, there is but little indication of folding, and a series of north-south faults throwing to the east would furnish a satisfactory explanation of the existing conditions.

Local Geology.

FRANKLIN COUNTY.

Belmont.

In the extreme north-western portion of Ellenburgh township, Clinton county, is a low ridge of gneiss whose edge reaches further north than any other exposure of the New York Pre-cambrian rocks, the small outlier at Burke excepted. It is flanked on the north and west by most excellent exposures of basal Potsdam, consisting mainly of massive arkose conglomerates, which reach over the border into Franklin county. Thence westward the level drops sharply into the Chateaugay valley, which is heavily drift-filled on its eastern side, so that no rock shows, and the boundary here is uncertain. Like so many of the Adirondack valleys, the river here seems to occupy a fault line. On the west the river hugs the side of a ponderous ridge of gneiss which extends northward to the town line. Somewhat more than a mile further down stream commences the series of excellent Potsdam exposures which culminate in the "Chasm" at Chateaugay village. Still further down stream the overlying Calciferous shows near the mouth of Marble river. The section here has been measured and described by Mr. Walcott.* It shows the upper 250′ of the Potsdam, but gives no notion of the entire thickness of the section along this line.

Passing westward through Belmont the gneisses come up to the boundary in a series of low ridges separated by shallow depressions filled with drift. The gneisses consist here of the red, poorly foliated, microperthitic variety, alternating with dark grey plagioclase-pyroxene gneisses, in which the feldspar is oligoclase or andesine and the pyroxene the aegerine-augite variety. The former predominate toward the east and the latter to the west, but the two occur interbanded in every section. There are also the usual dike-like bands of gabbroic and dioritic gneiss. With the exception of the exposures in the Chateaugay river but one outcrop of Potsdam sandstone was seen in the township in the vicinity of the gneisses. The exposure occurs in a depression between two ridges of gneiss, and shows several layers of coarse, somewhat pebbly rock, which is very quartzose and of light-brown color. Numerous loose blocks occur wide-spread in the vicinity, some of which are of very

* Bull. U. S. G. S. No. 81, p. 343.

coarse conglomerate, though these also do not agree in color and composition with the basal Potsdam as it usually appears. These loose blocks are manifestly not far removed from their parent ledge.

Burke.

In Burke township is a small and interesting Pre-cambrian outlier, at a distance of over five miles from the main boundary. The rock is well exposed in the Trout river at Mackenzie's mill, half-a-mile north of Burke post-office, and thence may be traced westward for one-third of a mile, the outcrops covering a wedge-shaped area with the apex at the mill, and the base to the west. Both to the east and the west the rock passes beneath heavy drift, concealing its extent in those directions, but Potsdam sandstone crops out near at hand to the north and south. In the former direction and only 100 yards down stream is a twenty-foot cliff of hard, yellowish sandstone, here abruptly cut off. A half-mile to the south, at the village, similar sandstone appears in the stream, dipping in the other direction. The accompanying section shows the observed relations. The sandstone has the lithologic characters which mark the middle and upper portions of the formation, and the writer sees no way of accounting for the structural relations here exhibited except on the assumption that the gneiss is brought up by a pair of faults.

The exposures here show a red, well-jointed, acid granitic rock composed of quartz and microcline or microperthitic orthoclase and a little magnetite. At the mill two large dikes constitute half the exposure. The southerly one is of syenite porphyry and is 27′ wide with the south wall not showing. Thirteen yards north of it is a 15′ dike of a diabasic rock which differs somewhat from the normal diabases of the region and is very coarse grained. A few rods to the westward, in the woods, are two other dikes, both of normal diabase, one of which is noteworthy in that it contains numerous inclusions of the wall rock scattered through it, commonly of small size. Such inclusions are not a common feature in the Adirondack diabases.

FIGURE 1. Section north of Burke village

The occurrence of this Pre-cambrian outlier, probably brought up by faulting, suggests interesting possibilities in the way of other occurrences of like nature, now concealed beneath the drift.

Malone.

In this township the boundary pursues a west-south-west course nearly to the western line of the town, when it bears away to the north along the edge of Cornish hill, a massive ridge of gneiss which extends well up into Bangor. As in Belmont, low ridges and spurs of gneiss protrude through the drift along the boundary, separated from one another by shallow, drift-filled depressions.

The gneisses are of the same general character as in Belmont. The two extreme varieties are, on the one hand, red, acid gneisses, composed of quartz and microperthitic orthoclase with magnetite and varying amounts of dark green-brown hornblende, and on the other, grey, more basic gneisses, made up of plagioclase, orthoclase, aegerine-augite and titanite, with or without hornblende and quartz. Sometimes one or the other of these attains considerable thickness, but ordinarily the two are interbanded, the bands not exceeding a few inches in thickness, and the one rock grading into the other. The resulting rock is therefore well banded, but neither in structure nor composition does it give any hint of a sedimentary origin. The customary dike-like bands of hornblendic gneiss occur in all exposures of any extent.

An interesting garnetiferous gneiss was found in the township outcropping near the road one-half mile east of District School No. 6. It is a nearly black gneiss and occurs interbanded with a reddish pyroxene gneiss of intermediate composition. Garnets, which are so deeply colored as to be almost black, make up nearly half the rock. In thin section they become transparent in deep yellowish-brown tones. The resemblance to colophonite is strong. A careful qualitive test made by Prof. E. W. Morley shows the presence of titanium in small amount, and the color is probably due to it. In addition to the garnet the rock is mostly made up of microperthite, but holds also a little aegerine-augite, oligoclase and quartz.

But two localities were found in Malone where the Potsdam was exposed near the boundary. The first is along the Adirondack railroad about two miles south of Malone, where 15′ of red, thin-bedded, feldspathic sandstone are exposed at the south end of a cut within 100 yards of massive exposures of red, microperthitic gneiss banded with pyroxene gneiss. The dip is in the normal direction and is not high, 10° to N. 35° W.; the character of the rock indicates the basal portion of the formation and there is no sign of faulting.

The second locality is a mile and a half distant and one mile east of School No. 6. Here in a field south of the road, lying in an embayment between

two gneissic ridges and with gneiss within a quarter-mile on each side, is a knoll of hard, well indurated, red and white banded sandstone which has been somewhat quarried. The location of the exposure, the 25° dip and the fact that the horizon in the Potsdam is somewhat above that of the previous exposure, indicate that the presence of the sandstone here is owing to dislocation.

The higher portion of the formation is well shown in the river at Malone and thence northward, it being quarried considerably about a mile north of the city. Beyond, occasional outcrops are found along the river for a distance of several miles before the Calciferous is reached near Westville. For about half of this distance the inter-stratification of grey dolomite with the white sandstone indicates the presence of the passage beds to the Calciferous, which apparently occupy the centre of a shallow synclinal trough, as the north-westerly dip beyond is replaced for some distance by one to the south-east. The wide extent of surface underlaid by the Potsdam here is thus explained. In the passage beds at this place are iron-grey sandy dolomites presenting a peculiar appearance, and such are found to characterize this horizon throughout northern New York. On the fresh fracture, glittering cleavage faces are shown a half inch or more in length and dotted in a psuedo-pœcilitic fashion by numerous rounded quartz grains, giving a peculiar satiny lustre. The thin section furnished the explanation. The rock is a fine mosaic of dolomite crystals in which are streaks numerously set with somewhat rounded grains of quartz. In the quartzose bands are frequent areas in which the cement enclosing the grains has the same extinction throughout. In these cases the matrix is found to be of calcite instead of dolomite. In the sandy streaks then, rather coarsely crystalline secondary calcite has been deposited around and including the quartz grains, its good cleavage manifesting itself when the rock is broken.

Bangor and Brandon.

The only Pre-cambrian rocks exposed in Bangor are the gneisses of Cornish hill which extend northward four miles beyond the average line of the boundary. Following the west side of the ridge the boundary passes into northern Brandon, then swerves to the westward and continues in that direction across the township into Dickinson.

The gneisses exposed are quite homogeneous and consist mainly of microperthitic gneiss in the eastern, and microcline gneiss in the western half of the township, the two having the same color and appearance and grading into one another. Hornblende is present in variable amount in all the exposures, and

the rock is well foliated. The more strongly acid gneisses are well jointed, the ordinary gneiss lacking this structure; the former may represent the later granites, decisive evidence on this point not having been found. The pyroxene gneisses, which are such a feature in Malone and Belmont, are mainly lacking here, though they are present to some extent. Considerable gabbro-diorite gneiss occurs together with the usual dikes of hornblende gneiss. Near the west line of the township are widespread exposures of acid granitoid gneisses, which alternate with masses of gabbro-diorite gneiss of considerable thickness. The two blend into each other along their contacts.

The Potsdam sandstone makes but meagre showing in these townships, the drift being very heavy. In the stream at South Bangor there are slight exposures of a buff, hard, coarse sandstone. There is an old quarry on the Bangor-Brandon line from which a slight amount of stone has been taken, the rock here being white and not well indurated. One mile to the south-west the red, hematitic arkose of the basal portion of the formation is poorly exposed by the roadside only a few yards away from the gneisses. This was the only outcrop lying close to the boundary observed in the township.

Dickinson.

In this township the boundary trends to the south-west. In the north-eastern corner the gneisses are well exposed at the end of a low ridge with Potsdam sandstone close at hand to the north. The entire western flank of the ridge is, however, so thoroughly drift-covered that no exposures are to be found until those opened by the Deer river are reached, so that the boundary here is uncertain though the topography indicates a position approximately as shown on the map. At Dickinson Centre and thence westward to the county line and beyond, outcrops of gneiss are plentiful with, in one case, the Potsdam in place only a few yards away.

The gneisses in the north-eastern part of the township are for the most part red, acid gneisses of microcline or microperthite and quartz, often coarse and full of quartz and pegmatite veins, as is usual in these gneisses. With these are narrow, sharply defined basic bands of hornblende gneiss which constitute but an insignificant proportion of the whole.

Around Dickinson Centre and for a mile and a half eastward, the rock is largely gabbro-diorite gneiss. This grades on the one hand into hornblende gneiss (diorite gneiss) and on the other into a red orthoclase gneiss which carries the same aegerine-augite and deep orange titanite which are found in the gabbro-diorite. This in turn gradually shades into the ordinary red

granitoid gneiss of the region. These relations are well shown one-half mile north-west, and again the same distance south of the Centre. At the latter locality a hornblende gneiss at the base of the section grades upward into gabbro-diorite and this in turn into red orthoclase-quartz gneiss. A considerable biotite content characterizes some of the gneisses here and is worthy of note as it is not an important mineral in most of the basal gneisses.

The gradual passage of one kind of gneiss into another in this region is not thought to possess the significance which would attach to it in an unmetamorphosed district. It is so general, and the rocks concerned are often so diverse that it would seem to have been produced during the metamorphism of the region and therefore to be secondary, instead of representing an original structure due to community of origin. North-west of Dickinson Centre quite massive gabbro-diorite is seen passing over into red orthoclase gneiss, not however by a gradual change but by the most minute kind of interbanding of the black and red gneisses, both of which here have a composition intermediate between that of the two extreme varieties.

One mile west from the Centre on Macomber's farm, is a ledge of Potsdam sandstone outcropping one-fourth mile south of the road. It is red in color and thin bedded, but hard and firm and has been quarried somewhat for local use. It has the usual moderate dip to the north-west. To the south it shows cut off edges, a marshy tract intervenes, then at a distance of 75 yards appears a massive wall of red, acid, microcline-quartz gneiss. This kind of topography prevails where the gneiss and the sand stone are found near together and may perhaps be accounted for by the easily erodable character of most of the basal Potsdam.

East and west of Dickinson Centre along the Deer river are heavy sand deposits which cover considerable territory. They are on nearly the same level as the upper sand at Malone, but probably represent deposits along stream made by the river during its flooded condition following the retreat of the ice sheet, while local glaciers may have still lingered in the Adirondacks.

ST. LAWRENCE COUNTY.

Hopkinton.

The boundary pursues a nearly east and west course across this township. It presents certain differences in character when compared with the boundary in Franklin county, owing to the fact that the gneisses here strike east and west so that the ridges run parallel to the boundary instead of coming up to it, while depressions are less frequent and cut across the strike. Out-

crops of Potsdam sandstone are more numerous close to the boundary in this township than in any other part of the district examined.

The gneisses along the boundary in Hopkinton are quite homogeneous and quite similar to those already described, their main distinction being the not infrequent occurrence of considerable biotite, this being especially true of those in the western half of the town.* In the eastern half they are mainly well foliated orthoclase or microcline gneisses with the usual variations in structure and texture and in the amount of quartz present, containing also varying amounts of plagioclase and hornblende and sometimes biotite. The usual bands of diorite gneiss occur plentifully. In an exposure on the Meacham farm, two miles south of Nicholville, is a dike-like band only 18 inches wide cutting the gneiss, and this furnishes the best and least metamorphosed specimens of the basic, ophitic gabbro which the writer has yet seen in the Adirondack region.

The Potsdam, as exposed in the township, possesses considerable interest. Near the roadside at the Meacham farm and near the gabbro just discussed are the outcrops mentioned on a previous page, † a low knoll of very coarse, rotten, acid gneiss crossing the road, followed to the south at a distance of 15 yards by exposures of a coarse, feldspathic conglomerate which disintegrates with great readiness. The conglomerate is composed of debris from the gneiss and occupies a depression in its surface, as gneisses appear again in force a short distance further south.

One mile to the eastward, on a lane running south from the main road, is an old quarry opening in a single ledge which protrudes through the drift. The rock is a well laminated, coarse sandstone, in white and buff or brown colors, and has the abnormal dip of 18° to S. 20° E. It seems to represent an horizon well above the base of the formation and its attitude suggests dislocation. It lies, however, in a wide depression with no other outcrops near at hand.

One and one-half miles west of the Meacham farm exposures and less than two miles south of Hopkinton village, a ledge of red, feldspathic sandstone, containing also much magnetite sand, is well exposed by the roadside and for some distance to the westward, with the normal low dip to the north-west. Only ten yards south of it and parallel with it on the west, is a ridge of very coarse acid gneiss. There is no evidence of faulting between the two. One mile to the northward is Budd's quarry where a firm, red stone, often prettily banded

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* As Professor Smyth is engaged in a detailed study of the Pre-cambrian rocks of St. Lawrence county, they will be but briefly referred to here.

† Page 14.

with white is opened and has a considerable local use. White sandstone is exposed by the river at Nicholville, and near Fort Jackson much quarrying is done in white and buff sandstone. Westward from this line of outcrops no Potsdam was seen in the township.

Parishville.

In this township the boundary at first bears to the north to enclose the massive but low ridge of gneiss lying to the northward of Parishville village. The exposures are excellent and show a well foliated gneiss of intermediate composition, for the most part with a considerable bi-silicate content which is usually hornblende. This is sometimes replaced by a pleochroic augite. Biotite is also a prominent ingredient and a little muscovite shows in some of the slides. The predominant feldspar is plagioclase, either oligoclase or andesine, but orthoclase, microcline and quartz are present in considerable amounts.

Just to the westward of Parishville village, the Grenville series comes to, and forms the boundary. Rocks which unquestionably belong to that series are separated by ridges of gneiss of uncertain relationship, but these excepted, the Grenville series remains at the boundary as far as the work was carried. The unequal resistance to erosion presented by the various members of this series, coupled with the fact that the general altitude of the country is much below that to the eastward so that erosion does not go forward so rapidly, combine to render the boundary very uncertain, both because of the exceedingly erratic distribution of the Potsdam and because it rarely shows in outcrop.

These rocks will be described by Professor Smyth. It may be said in general that the gneisses in this series differ from the older gneisses in being for the most part much more finely and evenly granular and in having, in many of the beds, abundant biotite as the only ferro-magnesian mineral.

The Potsdam was found exposed in but two localities in the township, both along the brook which empties into the river one mile west of Parishville. The best exposures are about a mile up the brook and consist of coarse sandstone of medium induration, striped in white and flesh color, or white and buff. The other outcrop is further north where the road from Parishville to Parishville Centre crosses the brook, and the exposure is but meagre. These rocks lie in a trough eroded in beds of very quartzose gneiss which oppose but feeble resistance to degradation. Sufficient data were not obtainable to admit of determining whether the Potsdam owes its present position to faulting or

to original deposition. It is quite possible that it reaches further south than is indicated on the map.

To the southward, in Colton, crystalline limestone outcrops in association with the gneisses which here appear. One mile south of the main Potsdam exposure, the brook shows an excellent section of the quartzose gneisses on each bank, along with some curious rocks of very uncertain origin, and in any event profoundly changed from their original condition. The exposure is mentioned here as it is of great interest, yet is an easy one to miss.

Pierrepont and Potsdam.

The boundary so far as traced in these towns is shown on the map accompanying this report. More detailed areal work would probably necessitate considerable changes as the relationships here are complicated, and the drift very heavy. The rocks of the Grenville series are well shown and possess great interest.

The Potsdam sandstone in the vicinity of Potsdam shows features of importance, and the accompanying map (Figure 2) has been prepared to show in detail the conditions along the river south of the city. Both east and west of the city the Grenville gneisses reach as far, or nearly as far, north as the city itself. They are even found in the city itself. But the river valley is so heavily encumbered with sand deposits and other drift that the limits reached by these rocks are completely hidden. Along the river, however, outcrops of Potsdam sandstone are found for a distance of six miles south of Potsdam, and probably extend still further in the same direction. The structure is sufficiently well shown to prove that it owes its position and attitude to faulting.

Northward from Potsdam, the upper beds of the sandstone are shown along the river, with the customary low north-westerly dips, followed by the passage beds, and, just below Norwood, by the Calciferous. These are all with the same dip, and manifestly in a continuous and undisturbed section. At Potsdam, as shown by N. H. Winchell, gneisses of the Grenville series outcrop in the river and in the city itself.* The heavy drift covering east and west prevents tracing this rock to any connection with Grenville exposures in those directions, but it seems most probable to the writer that it is brought up here by a fault. The absence of all the lower portion of the Potsdam formation in the exposures to the northward, and the high dips and disturbed character of

* Geol. Surv. Minn. 21st Am. Rep. pp. 103-104.

These outcrops were not seen by the writer, but a letter just received from Professor Winchell verifies the statements made in his report. The presence of this gneiss is the cause of the rapids in the river at Potsdam.

the exposures of the same formation to the southward harmonize with this view.

At Clarkson's quarry, three miles south of Potsdam, the rock is a firm red sandstone which is so cross-bedded and jointed that it is not easy to make out the true dip, which is, however, somewhat to the south of west.

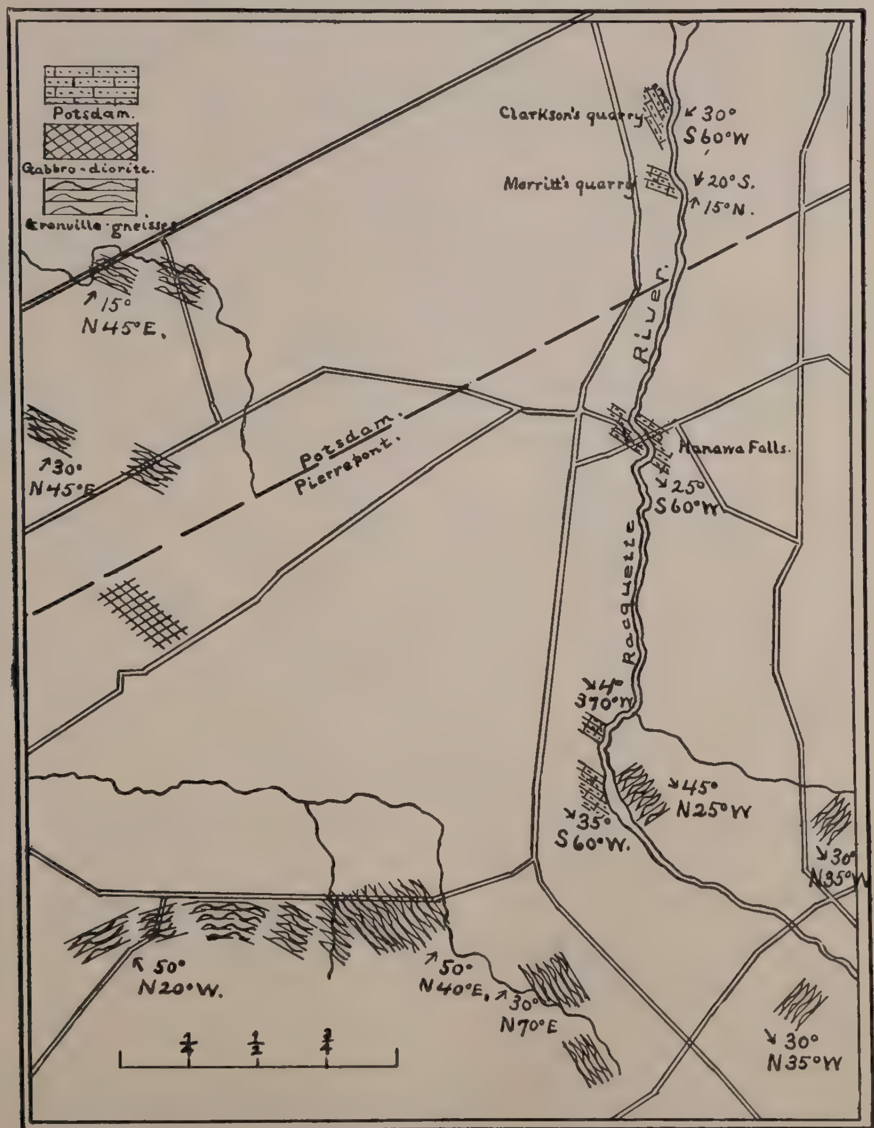

Figure 2. Map of a portion of Potsdam and Pierrepont Townships.

The lithologic character of the rock suggests an horizon low in the formation. A short distance further south, at Merritt and Tappan's quarry, the flesh-colored stone is banded with white and the structure is synclinal, as shown by N. H. Winchell.* Nearly a mile further south are excellent

*Loc. cit. p. 101.

exposures at Hanawa Falls, where the rock is prevailingly red and massive, the dip to the south-west has been resumed, and the horizon seems much the same as at Clarkson's.* Still another mile to the south is Elliott's quarry where the rock is light colored, being merely tinged with red. The dip is still to the south-west though here it is quite low.

One-fourth mile further south are most interesting exposures on both sides of the stream, at the site of an old mill. The west bank is formed of Potsdam sandstone, here of white color and with a south-west dip. It must lie higher than the rock at Elliott's quarry, and apparently is at a higher horizon than any other seen south of Potsdam. The east bank of the stream, which is here only a few rods wide, is composed of rotten pyritiferous, quartzose gneisses, much stained by hematite in their upper portion, which belong to the Grenville series. The river just here is clearly occupying a fault line, to the presence of which the disturbed character of the Potsdam is due. Drillings for hematite ore not far east of the river, show apparent Potsdam conglomerate overlying the Grenville rocks, so that the throw of the fault is probably not excessively great.

To the west of Potsdam is a great development of kame and drumlin-like drift hills. The boundary indicated on the map merely connects the most northerly Pre-cambrian outcrops seen, and in the absence of Potsdam outcrops to the northward, must be regarded with considerable suspicion. The only exposure seen was a meagre one at West Potsdam.

The Calciferous Formation.

No attempt to make a section of the Calciferous was undertaken. With one exception all the outcrops seen were in close proximity to the Potsdam and merely represent the basal portion of the formation. The rock exposed is a hard, iron-grey, often sandy dolomite, occasionally with nodules of coarsely crystalline calcite, and quite like the layers of dolomite in the passage beds.

In the Racquette river north of Norwood near the Norfolk-Potsdam line, the rock exposed differs somewhat from the foregoing, being a quite pure blue dolomite. One layer in particular is quite fossiliferous though the fossils are not easily obtained in good condition. Quite a variety of forms are present here, including species of *Asaphus*, *Orthoceras*, *Nautilus*, *Pleurotomaria* and a little *Murchisonia* which is identical with the species occurring in the *Ophileta* beds at Beekmantown, Clinton county The locality is at the

* Ibid. p. 104.

bridge over the river on the town line. It seems further south than the one mentioned by Winchell and from which his party obtained fossils.* The horizon can not be far above the base of the formation, if undisturbed.

Dikes.

In following the boundary across Franklin county, eleven dikes were noted cutting the Pre-cambrian rocks. These were all in the eastern half of the county. In St. Lawrence not a single one was seen in the belt examined, and Professor Smyth's work shows them to be rare in most of that county. In the eastern Adirondacks they are exceedingly abundant and the same is true further westward at the Thousand Islands as described by Smyth, who has demonstrated them to be there of Pre-cambrian age.†

Of the eleven dikes, ten were of diabase and one of syenite porphyry. Nearly all the diabases contain olivine. One of them is noteworthy in that it contains frequent large phenocrysts of a light green, almost non-pleochroic orthorhombic pyroxene, probably enstatite, a mineral not of common occurence in diabase.

A more detailed description of the dikes will be printed elsewhere.

* Minn. Geol. Surv., 21st Ann. Rep., p. 109.

† Trans. N. Y. Acad. Sci., Vol. XV, p. 51.

THE NAPLES FAUNA

(FAUNA WITH MANTICOCERAS INTUMESCENS)

IN WESTERN NEW YORK.

By John M. Clarke.

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Geological Introduction.

The time period characterized by the culmination of the cephalopod species, *Manticoceras intumescens*, Beyrich, is clearly defined in many countries and is commonly regarded as marking an early stage in the closing phases of Devonian life and time.

The assemblage of species manifested in the several local developments of this zone of life forms is found to be variable within certain limitations. That which we are about to consider, to which we have previously applied the term *Naples fauna*, presents numerous traits which bring it into close relationship to the Intumescens-zone of Devon, Belgium, the Rhine, the Hartz, and the west and east slopes of the Urals. In none of these, however, are its individual, specific and generic features so fully reproduced as in the association described by Holzapfel* as occurring at Martenberg, near Adorf, in Westphalia.

This Intumescens-fauna has clearly manifested itself in cisatlantic palæozoic provinces only in the western part of the State of New York; in passing westward from the meridian of Cayuga lake its distinctive organic features become gradually disentangled and isolated from the dissimilar but geologically contemporaneous eastward fauna; they become predominant throughout Ontario, Livingston, Genesee and Wyoming counties; still further westward its faunules gradually become less prolific, decline in unity and, so far as our observations now extend, no evidence of the assemblage has been found beyond the western boundary of this State.

* Palaeontographica Neue Folge, vol. viii, 6, xxviii. 1882.

This peculiar association is not only distinctively different in its organic elements from the faunas which immediately precede and follow it, but also from those contemporaneous with it in adjacent regions.

The formation in which this fauna is involved, the *Portage group*, was defined more than a half century ago by Professor JAMES HALL, its boundaries were set, its westward extent determined, and, at various times since, several of its species described. Some further accounts of its geologic relations and organic constitution have been given by others, especially during the past twelve years.*

For the purpose of apprehending the stratigraphic conditions in which this fauna is involved, they are briefly restated in the following pages. As many of the important species of the fauna, with the exception of those here especially considered, are still undescribed, previous studies have been prosecuted at somewhat of a disadvantage. This paper is an introductory instalment of what is hoped may prove a reasonably full presentation of the organic components of this zone.

The succession of strata exhibited in a series of beautiful exposures along the course of the Genesee river was described in some detail by Professor JAMES HALL in the fourth "Annual Report of the Survey of the Fourth Geological District of New York" (1840).

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* The original accounts of this formation are found in the following reports:

JAMES HALL, Annual Report on the Survey of the Fourth Geological District, 1840.

Ditto, Geology of New York: Report of the Fourth Geological District, 1843.

Later publications in which especial consideration is given to these rocks and their contents, are:

JAMES HALL, Palaeontology of New York, vol. 1, 1884–5; part 2, 1879.

JOHN M. CLARKE, On the Higher Devonian Faunas of Ontario County, N. Y.; *Bull. No.* 16, *U. S. Geol. Surv.*, pp. 1–72, pls. 1–3, 1885.

Ditto, A Brief Outline of the Geological Succession in Ontario County, N. Y.; *Fourth Ann. Rept. State Geol.*, pp. 9–22, 1885.

Ditto, Die Fauna mit Goniatites intumescens, Beyrich, im westlichen New York; *Neues Jahrb. für Mineral.*, 1891, Bnd. 1, pp. 161–168.

Ditto, The Fauna with Goniatites intumescens, Beyrich, in western New York; *American Geologist*, Aug. 1891, pp. 86–105.

Ditto, The Discovery of Clymenia in the Fauna of the Intumescens zone (Naples beds) of western New York, and its geological significance, *Amer. Jour Science*, vol. xliii, pp 57–52, 1892.

Ditto, The Protoconch of Orthoceras; *American Geologist*, vol. xii, pp. 112–117, 1893.

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H. S. WILLIAMS, On the Fossil Faunas of the Upper Devonian, along the meridian of 76° 30′, from Tompkins county, New York, to Bradford county, Pennsylvania. *Bull. No.* 8, *U. S. Geol. Surv.*, pp. 1–36, 1884.

Ditto, The Fossil Faunas of the Upper Devonian: The Genesee section, New York; *Bull No.* 41, *U S. Geol. Surv.*, pp. 1–123, pls. 1–4, 1887.

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CHARLES S. PROSSER, The Thickness of the Devonian and Silurian Rocks of western central New York; *American Geologist*, Oct. 1890, pp. 201–211.

Ditto, The Thickness of the Devonian and Silurian Rocks of western New York, approximately along the line of the Genesee river; *Proc. Rochester Acad. Sciences*, vol. 2, pp. 49–104, 1892.

Ditto, The Thickness of the Devonian and Silurian Rocks of Central New York; *Bull. Geol. Soc. Amer.*, vol. 4, pp. 91–118, 1893

D. D. LUTHER, Report on the Geology of the Livonia Salt Shaft; *Thirteenth Ann. Rept. N. Y. State Geol.*, pp. 21–130, 1894.

The beds which lie directly above what was there termed the "upper black shale" (thus contradistinguished from the "lower black shale," the former now known as the Genesee slate and the latter as the Marcellus shale) were designated as the Cashaqua shales, taking their name from the creek entering the Genesee river from the east at Mt. Morris. These are olive-green or grey clay shales alternating with bituminous shaly beds and with interbedded thin shales, sandstones and flags. Upward in the rock series there is in general, a gradual increase in the amount of arenaceous sediment, the sands and flags becoming increasingly predominant and the shale beds themselves more arenaceous. While the transition to these beds from those below is in all respects an easy one, yet there is a possibility of distinguishing them in the mass, and hence the upper beds were termed the "Gardeau or Lower Fucoidal Group"; the adjective term referring to the abundance of the so-called "*Fucoides graphica*" over the lower surfaces of the flags. A thick mass of heavy bedded greenish or grey feldspathic and quartz sandstones above the Gardeau flags, representing the culmination of arenaceous sedimentation of this cycle, was termed the "Portage or Upper Fucoidal Group"; many of the layers containing vertical annelidan borings filled with mud, which have commonly passed under the name of "*Fucoides verticalis*."

In recognition of the fact that the distinction thus instituted in parts of this series would be difficult of application in actual practice, the same author, in 1843, applied the term "Portage or Nunda Group" to the entire series lying between the uppermost beds of the Genesee slate and the upper limit of the heavy beds of Portage sandstones. Since that date not only have the rock strata thus delimited in these western sections of New York, been known in geologic literature as the "Portage Group," but this term has been also, and properly, applied to all formations in whatever sections of this State and bearing whatever faunas, between the horizon of the Genesee slate beneath and the earliest strata characterized by the incoming Chemung fauna above.

Recent investigations indicate that the historical delimitation of the Portage group in the typical Genesee section does not express the complete upward range of the fauna of this group. In the Genesee valley, the Portage sandstones are overlaid by sandy shales and thin sandstones from one to two hundred feet in thickness and, in lithologic character, not unlike the Gardeau layers beneath; and through these beds the Naples or Intumescens-fauna ranges, with slight accretions. Strictly speaking, this fauna is mainly confined to the more argillaceous layers, while toward the top, a Chemung fauna

appears in the more arenaceous strata. But this alternation concerns only the upper portion of these beds. To this series of strata representing the prolonged existence of the Naples fauna the term *Wiscoy shales and sands* has been applied. In protracting, upon the evidence of the contained fossils, the scope of the Portage group to include these beds, we shall not appear to violate propriety for they did not escape the observation of Professor HALL, who at the close of his description of the Portage group says (1843, p. 248): "The Portage sandstone is succeeded by olive shaly sandstone and shale and this by black micaceous slaty shale with septaria; to this follow shales and coarse sandstones with fossils of the Chemung group." Their position is illustrated in the section along the Genesee valley from Portage southward, given on plate xi of the work cited.

The fauna of the typical section of the entire Portage series along the Genesee valley, is the fauna of *Manticoceras intumescens*. Not alone does this species here appear, become profuse in individual development and varietal expression, culminate and decline, but its associates are of a peculiar sort which likewise, for the most part, here appear, flourish and depart. Such are other forms of the genus *Manticoceras*, species of *Gephyroceras*, *Beloceras*, *Probeloceras*, *Tornoceras*, *Bactrites*, *Clymenia*, numerous forms of *Buchiola*, "*Cardiola*" and other genera of Cardioconchs, and the "Lunulicardiums," *Chænocardiola*, *Pinnopsis*, *Pterochænia*, *Honeoyia*, as well as a few specific forms of gasteropods. No less characteristic is the dearth of brachiopods.

Through the early part of the period this is the fauna of all the sediments, shales, calcareous layers and nodules, and sandstones wherever the last are found to bear fossils; through its latest phases it is distinctively the fauna of the shales and not of the sandstones, but it is then that the fauna was retreating and readvancing, with the appearance and temporary withdrawal of the Chemung fauna about to prevail. In following the Portage series in its entirety to the east through Yates, Schuyler, Tompkins and into Cortland and Chenango counties, we find that its western fauna is gradually and wholly replaced in the rock series. Species of the genera above mentioned rapidly disappear and their places are taken by strangers to the western sections, especially by brachiopods and lamellibranchs similar to those occurring in the Hamilton fauna below, so that through Tompkins county and in the meridian of Ithaca we encounter a commixed association, the interleaved edges of the two adjacent faunas of the west and central areas. Where the strain of the eastern fauna is the purest, as in Cortland and Chenango counties; where it

is fully relieved of entanglements with the fauna of the west, it has been termed the Otselic fauna.*

East of the Ithaca meridian, in Cortland and Chenango counties, the rock section above the Tully limestone consists of, first, a few feet of black Genesee slate essentially without fossils; then a mass of sandy shales and flags, from 250 to 300 feet in thickness. These strata are almost devoid of fossils but those thus far found indicate some relationship to the Naples fauna. Professor C. S. PROSSER has recently called attention to the fact that to these strata as exposed at Sherburne, in the upper Chenango valley, the late LARDNER VANUXEM applied the term "Sherburne sandstones." PROSSER has, further, demonstrated the persistence of these beds westward into the Ithaca section, and proposes, with these excellent reasons, to recall this early name. West from Tompkins county this division soon loses value. Above the Sherburne sandstones appears the series of arenaceous shales to which the term Ithaca group has been applied. We have noticed above, that the fauna of these beds is, in general, a reproduction of the Hamilton fauna below, less rich in species, indeed, but with few that had not already been in this province during Hamilton time. Some forms unknown in the Hamilton fauna or modified expressions of Hamilton species are introduced with these sediments. Thus, for example, *Leptæna rhomboidalis*, a species not known in the Hamilton fauna, occurs here; certain forms of lamellibranchs which are but mutational expressions of a Hamilton specific type, *Actinopteria Boydi*, characterize the horizon. The fauna becomes gradually weaker in Hamilton traits as it continues upward in the rocks and the later appearance of the species *Spirifer mesastrialis* marks a change of expression, this shell becoming thereupon the leading index fossil in the faunas of the upper strata.

In passing still further eastward a new lithologic and palaeontologic element enters into the composition of the Portage group. Approaching the Chenango river we meet with a considerable thickness of red and green shales and sandstones bearing, not infrequently, fish remains, and, in isolated localities, the *Unio*-like fossil, *Amnigenia Catskillensis*, Vanux. (sp). This is the Oneonta group, whose position is above the lower Otselic flags and perhaps the lower portion of the upper Otselic flags, but which, for the most part, seems to replace in this region the latter formation, the two passing into each other as synchronic

*It would be a convenience in terminology if we had a term to express precisely the time significance of a fauna so peculiarly placed as is this typical Portage fauna. Here is the fauna of a sharply defined province clearly set apart from those of contiguous synchronic provinces. It would be an inexact use of a term to express its duration in Professor BUCKMAN'S word *Hemera*, for the hemera of *Manticoceras intumescens* must mean the entire lapse of time represented by Portage sediments everywhere, while in eastward sections of these sediments outside the boundary of the Naples province, *Mantic. intumescens* and its peculiar organic associates are not present. The term needed is one which will express at once the time unit and the geographic restriction of the fauna, one which will specify the duration of a particular faunal province, as one should say, the *Zoehemera of Mantic. intumescens*.

deposits of adjacent provinces. The Oneonta formation thus represents the later portion of Portage time in the sections along the Chenango river and to the east. The formation is continued into the Helderberg mountain and the more southerly foot hills of the Catskills.*

Above the Oneonta sandstones the fauna of the central region is but sparingly represented, and when so, in association or oscillation with a true Chemung fauna, in the normal manner of replacement of a given fauna by its successor in the same province.

In regarding the various faunas above considered as distinct organic associations coexistent during Portage time in this geographic amphitheater of New York, interpolated outliers or stragglers from each are to be expected in the provinces of the others. Thus in the western or Naples province there are occasional appearances of species usually brachiopodous, which appertain to the adjoining eastward or Cortland province. Now and again are to be found thin sandstones which contain such forms as *Leptostrophia mucronata*, *Orthothetes* cf. *arctostriata*, *Productella*, *Strophalosia*, *Liorhynchus*; forms which do not strictly belong to the Naples fauna; nor are they associated with its species, being found in this region by themselves and rarely in the softer shales in which the Naples species especially predominate. Such straggling associations of the eastward species are small, and yet have sometimes gone surprisingly far afield, having evidently, from their fragmentary and massed condition, been carried in by the movements of the water. In similar manner we have observed some members of the Otselic fauna reappearing briefly above the Oneonta sandstones; *Spirifer laevis* and *Leptostrophia mucronata*, in the proemial Chemung fauna exhibited in the sections near Greene, Chenango county (See 15th Ann. Rept. N. Y. State Geol.1898).

From the foregoing brief consideration of these regionally approximate but distinct faunas which are included within the limits of Portage time, it will be clearly seen that while the term Portage group, signifying in its accepted sense the series of strata between the Tully limestone or Genesee slate† and the Chemung formation, has a definite value, there is no exactitude

* In the region east of the Chenango river the absence from the series, of the Tully limestone and Genesee slate, leaves a uniformity of lithologic composition to the strata both below and above this horizon. We owe to the careful investigations of Prof. C. S. PROSSER the determination in these arenaceous shales of the horizon of the Tully limestone, as marked by the presence of *Hypothyris venustula* (=*Rhynchonella cuboides*); *Fifteenth Ann. Rept. N. Y. State Geologist.*

† The Genesee slate has generally been classified in text books and referred to in the volumes of the Palæontology of New York and elsewhere, as the uppermost subdivision of the Hamilton group. While the disposition of such a fauna is often a matter of convention and while horizontal planes of division must be drawn, it is a truer expression of the faunal affinity of the formation to include it within the Portage group, as long ago suggested by the writer. This disposal of these beds was foreseen by Prof. JAMES HALL, who, in a foot-note to page 218 of his report on the Geology of the Fourth District (1843), made the following remark apropos of the name proposed for the formation; "From the circumstance that other shales above this appear in the same gorge [Genesee river at Mt. Morris], it would have been desirable to give another name; but no locality is known which is not more objectionable than this. Since it is very probable also, that this rock will in future be considered only as a member of the Portage group, its local name will be the more appropriate."

in the expression "Portage fauna," except as this name be applied to the fauna of the original Portage section. This can not be done without resultant confusion or laborious explanation with each use of the term. Hence we shall continue to use the term "Naples fauna" for the fauna of the original Portage section; the fauna of the zoehemera of *Manticoceras intumescens.*

The Vertical Range of the Intumescens-Fauna.

The Prenuncial Fauna (*Styliola limestone*). The name Styliola limestone has been employed in previous papers for a highly bituminous calcareous layer from one to four feet in thickness, which precedes the deposition of the shales and sandstones of the Portage group, and lies near the middle of the Genesee slates. In accordance with a measurement of its exact position in Bell's gully, Canandaigua lake, it would appear to lie at this meridian somewhat above the middle of these beds, with 112–127 feet below and eighty-five feet above it.

Mr. D. D. Luther found in the section of the Livonia salt shaft, westward of Canandaigua lake, where the thickness of the Genesee formation is notably diminished, that this layer had a thickness of four feet and lies eighty-six feet above the base and seventy-one feet below the top of the formation.*

The rock sometimes forms a continuous layer, is usually concretionary and often involved with shales, but however it may vary in these respects, a peculiar character is given to it by the myriads of *Styliola* (*Styliolina*) *fissurella* which almost everywhere enter into its composition. This calcareous layer, though thin, represents pretty much all the calcareous matter in these sediments, save that agglomerated into the form of concretions. It is a remarkably persistent formation for one so thin and has been traced from Middlesex, Yates county, to the shore of lake Erie.

This Styliola limestone plays an important role in our study the fauna of the Intumescens-zone. With the sudden ingress into the shallow seas of the Genesee epoch, of myriads of Styliolinas whose shells have furnished most of the calcareous matter for the limestone, came the first representative of *Manticoceras intumescens*, with a considerable company of species unknown before, but, with it, better represented afterward.

The species of the Styliola limestone are not those of the pre-existing seas of this region but those of the Intumescens-fauna. The majority now appearing for the first time, re-appear in the Naples beds, from which they are here separated by a heavy mass of bituminous, somewhat arenaceous shales. We have elsewhere summarized the correspondence in the fauna of this layer with that of the Naples† beds and have shown that this first appearance of the Intumescens-fauna was followed by a return of the normal Genesee conditions of sedimentation during which time a virtually complete migration

* *Thirteenth Ann. Rept. N. Y. State Geol.*, vol. 1, p. 107, 1894.

† Fauna with Goniatites intumescens, etc.

of the fauna was effected, stragglers here and there having continued for a while under the changed conditions, until the Intumescens-fauna comes back again into this region intensified in vitality and specific representation during the period represented by the Naples beds.

Such recurrences of faunas are to be always expected in the displacement of one fauna by its successor, and many excellent illustrations of such phenomena are afforded in the palaeozoic sections of this state. The writer has called attention to a recurrence of the fauna of the Marcellus shales after the introduction of the normal fauna of the Hamilton shales (Fourth Ann. Rept. N. Y. State Geol. p. 15, 1885); a recurrence of characteristic species of the Corniferous limestone above the base of the Marcellus shales (Thirteenth Ann. Rept. N. Y. State Geol. pp. 149–156, 1894), and a preliminary appearance of the normal Hamilton fauna in the midst of the Marcellus shales, in a persistent stratum which has been termed the "Stafford limestone" (Eighth Ann. Rept. N. Y. State Geol. p. 60, 1889; Thirteenth Ann. Rept. N. Y. State Geol. pp. 148, 157, 1894). In all of these instances the reappearing fauna accompanies a reiteration of its normal conditions of sedimentation. It will be observed that these occurrences are not all recurrences. Certain of them are introductory and incomplete representations of the fauna at its normal development; thus there are precurrent or prenuncial faunas, such as that of the Stafford limestone with reference to the Hamilton fauna, and that of the Styliola limestone with reference to the Naples fauna. Some are post-current faunas, imperfect representations of faunas whose normal or culminating development has passed, like the reiterations of the Marcellus fauna in the Hamilton shales, as just cited.

The Styliola limestone, thus, contains the prenuncial Intumescens-fauna. Its appearance was abrupt, and we shall have occasion to observe after close analysis, that in the great majority of its components it was an exotic fauna. This is emphatically shown in the inrush of goniatites and lamellibranchs novel to American faunas, all of forms which especially characterize this assemblage. With them are intermingled some species which may have persisted from previous faunas in the same region but they are few and less characteristic.

The Normal Fauna. The Naples fauna, or the normal Intumescens-fauna, is always best developed in the soft, compact, sandy shales of the lower part of the rock series. The bituminous deposits of the epoch of the Genesee are terminated by a gradual increase of arenaceous matter in the sediments, which eventually introduces greenish flags and rather thick sandstones as the basal strata of the Portage group.

In Seneca county, the Genesee slate is, as shown by the recent investigations of D. F. Lincoln, capped by a very impure bituminous nodular limestone,

not always continuous and not impregnated with *Styliolina*, but containing representatives of the Intumescens-fauna, some of which have been elsewhere observed only in the Naples beds above. It is an early appearance of these species not recorded in the more western sections.*

The interbedded soft shales of the lower part of the Naples beds bear most abundantly the characteristic fossils of the fauna. As the sandstones increase upward at the expense of the argillaceous sediments the fossils become less profuse. In the carefully studied Naples section, the continuation of this fauna is through a series of deposits measuring 599 feet,† that is to say, from the first appearance of greenish sandy sediments with representatives of this fauna to the first incursion of a distinct brachiopod fauna. This latter, foreign in its composition to that characterizing the Naples beds, occurs just below the heavy sandstones of the Naples section, which have been regarded ‡ as continuous with the original "Portage sandstones" of Professor HALL. This faunule embraces the following species:

Liorhynchus, a large shell at maturity, having the aspect of *L. quadricostatus*, but with well developed lateral plications;

Productella speciosa;

Atrypa reticularis;

Leptostrophia mucronata;

Ordiculoidea, sp.

This is not an association indicating any definite relationship to the true Chemung fauna, and may properly be looked upon as one of the already mentioned incursions into this region of species of the eastern fauna.

Less than one hundred feet above this horizon and at different intervals in the next five hundred feet, occurs a typical Chemung fauna with *Orthis Tioga* and Dictyosponges; and these beds are followed directly by the High Point strata carrying *Spirifer disjunctus*, *Rhynchonella pugnus*, etc.§

*An enumeration of the species of this faunule was given by the writer in Dr. LINCOLN's Report on the Geology of Seneca county (Fourteenth Ann. Rept. N. Y. State Geol., foot note to pp. 100–101, 1895.)

† LUTHER, in Thirteenth Ann. Rept. N. Y. State Geol., p. 119, 1894.

‡ In all previous papers bearing upon the thickness of the Portage formation in the Naples section the apparent extinction of the Naples fauna at the elevation above stated has been regarded as evidence that the heavy-bedded sandstones directly overlying that horizon were to be interpreted as equivalent to, and continuous with the original "Portage sand. stones" of the Genesee section. The discrepancy in the thickness to be assigned to the formation in these two sections has also been frequently referred to; in the Naples section it is about 600 feet, while in the Genesee section, with the addition of the Wiscoy beds above the Portage sandstones, the thickness is fully twice that. With our present knowledge this is still a proper statement of the unequal vertical range of the Naples fauna in adjoining regions. Latest investigations now indicate that the true horizon of the "Portage sandstones" in the Naples section is not less than 400 feet above the last appearance of the Naples fauna. These beds have been traced eastward from the upper Portage fall with much care by Mr. D. D. LUTHER and his observations suggest that there may be no such discrepancy in sedimentation in these two sections as has been before believed But these additional 400 feet of strata are permeated with Chemung fossils and, if they actually lie below the horizon of the "Portage sandstones" we are presented with a condition which not alone renders the employment of the term Portage difficult in any case but also emphasizes the early statement of Professor HALL (Geology of the Fourth District p. 249): "It may thus happen that the fossils so typical of the Chemung group commenced their existence in the eastern part of New York much earlier than in the western part; and, therefore, the strata equivalent in age to the Portage group may there contain fossils which at the west appear only at a later period."

§ A full list of the species of the High Point fauna is given in Bull. 16, U. S. Geol. Surv.; The Higher Devonian Faunas of Ontario county p. 72.

The following is, with our present knowledge, a proper expression of the time and faunal relations of the Portage sediments of western New York:

West — East

	Genesee river section		Naples section
ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Wiscoy beds	CHEMUNG FAUNA	
ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Portage sandstones	CHEMUNG FAUNA / ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Portage sandstones
ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Gardeau shales and flags	ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Gardeau shales and flags
ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Cashaqua shales	ZOEHEMERA OF MANTICOCERAS INTUMESCENS / NORMAL OR NAPLES FAUNA	Cashaqua shales
ZOEHEMERA OF MANTICOCERAS INTUMESCENS	Upper Genesee	ZOEHEMERA OF MANTICOCERAS INTUMESCENS	Upper Genesee
Z	Prenuncial or Styliola fauna	Z	Styliola fauna
	Lower Genesee		Lower Genesee

THE NAPLES FAUNA.

I. GONIATITINÆ.

Prefatory.

In the following pages an effort is made to elucidate the actual values of species of given or allied genera in a single fauna, and to express these values in terms of one another. Where fulness and nicety of data have justified, we endeavor to show how a species or variety may be interpreted in the light of a standard or prevalent contemporary type, and to construe the significance of variations in the several structural differentials.

The meanings of these structural features in the individual have been generally established by the labor of many students of cephalopods, but their application to the portrayal of the mutual relations in coexistent offspring of the same stock has not been so often attempted as to render new illustrations of these facts superfluous. These points are lost sight of in none of the forms considered, though they may be involved with descriptive detail. The purpose throughout has been less to seek phylogenic clues than to present ontogenic values.

GONIATITES (*vulgate*).

Family **Primordialidæ,** Hyatt.

Genus Manticoceras, Hyatt.

Type of Manticoceras intumescens, Beyrich.

In various of the papers already cited we have expressed the opinion that the species described by Professor Hall in 1860, as *Goniatites Pattersoni**, is throughout of the same specific type as that described by Beyrich at an earlier date as *Goniatites intumescens*. There can be no possible controversy on this point, which is confirmed not alone by the general agreement in all normal mature shells, but enforced at every stage of the more minute analysis to which the species is here subjected. It will presently be noticed that this form, which may be regarded as the normal expression of the specific type, is accompanied by other well defined variations of the same type.

Incidentally, in the comparison of our variations with the diverse forms referred by European authors to *Goniatites intumescens*, opportunity will be afforded of presenting the fact that, notwithstanding such variations of expression, the specific type is firmly maintained beneath such modifications. Just

* A bibliography of this and other local expressions of *Gon. intumescens* occurring in this fauna, is given at the close of the discussion of this species.

the precise value of corresponding deviations in the European expressions estimated with reference to local conditions, obstructed or accelerated development, can not be satisfactorily attempted in this connection.

The Generic Designation. The old genus GONIATITES was long ago conceded to be insufficiently precise as a generic designation. That it is still in vogue as a general application is due both to its great usefulness as a broad distinction from forms of similar aspect grouped together under such names as *Ammonites*, *Ceratites*, etc., the imperfection or incompleteness of its subdivisions and the impossibility of always recognizing full and precise generic characters in given material.

The old division has been resolved into many parts by recent writers and no doubt the many subdivisions which have been introduced will be found distinctions of preciser value and the term GONIATITES itself become restricted to the division containing the species upon which it was established (GLYPHIOCERAS, Hyatt).

Students of the goniatites have made their various generic distinctions not always from the same point of view, but it may be said that the propositions of HYATT, especially, and of v. MOJSISOVICS, WAAGEN and KARPINSKY were based not upon any single set of structural characters and variations; rather upon differences pervading the entire shell.

Professor HYATT introduced the term MANTICOCERAS (1884) for goniatites "with compressed and often very involute whorls, which are, however, directly traceable by the closest gradations into forms with broad whorls, open umbilici and an aspect similar to that of ANARCESTES. The young are invariably less discoidal than in GEPHYROCERAS, the abdomens rounded and the sides divergent outwardly. A close resemblance to *Agoniatites bicanaliculatus* or *tuberculoso-costatus* occurs in the costated young and in the sutures and form of *Mant. tripartitum* until a late larval stage. The adult sutures have the same general aspect as those of GEPHYROCERAS, but the septa in the compressed involute forms become more decidedly convex. The lobes remain rounded until later stages of growth, the funnel lobes are generally smaller, the larger lateral saddles are more persistent and retain their forms unchanged even in the extreme old stages of the largest specimens."* The type of this genus is pronounced to be *Goniatites simulator*, Hall, a form from the *Liorhynchus*-bearing beds containing the commingled Naples and Otselic fauna near or at Ithaca, N. Y. This species (or rather, specimen, for but the single example to which the specific name was originally applied has come within our knowledge) is pretty correctly figured in the Palæontology of New York, vol. v, pt. 2 (pl.

* Proc. Boston Soc. Nat. Hist., vol. 22, p. 317.

lxix, figs. 1, 2). The specimen represents a nearly entire, rather small though probably essentially adult shell with a characteristically broad venter, gradually rounding sides, but it is without such elevated dorsal margin and abrupt dorsal slope as there represented. It is important to indicate this, as the figure cited presents an aspect actually characterizing, in this conspicuous elevation of the dorsal margin, certain local expressions of *Mantic. intumescens.* The shell is re-figured on our Plate I, fig. 14. *Manticoceras simulator,* with its rounded lateral lobe is such a shell as the *Gon. carinatus* (not BEYRICH) of SANDBERGER and of TSCHERNYSCHEW, and while we are in ignorance of the surface character of its shell we may also bring into comparison the *Gon. lamellosus,* Sandb. and *Gon. lamed,* Sandb. var *complanatus* (Beyr.) Sandb.

The probability has, at various times, been suggested that such shells are either actual young of *Gon. intumescens* or stand as species in a phylonepionic position with reference to the ephebic normal of *intumescens,* for we shall presently observe that the acuteness of the lateral lobe in *intumescens* is an adult condition (HYATT, HOLZAPFEL) and *Mantic. simulator* itself shows an increasing sharpness in this lobe on successive septa over the last half of the final whorl. But in the normal form of *Mantic. intumescens-Pattersoni,* the lateral lobe has lost its roundness and become acute long before so great a size as that of *Mantic. simulator* is attained, and thus this species stands in a definite relation to the former, that of retarded to complete development. In the present discussion we regard this form as one of several abnormals of *Mantic. Pattersoni,* and as it is at least impossible to conceive a generic difference between its known structure and that of *Mantic. Pattersoni,* we apply the term MANTICOCERAS to the *intumescens*-group, and hold that *Gon. intumescens* must be regarded as its typical species. Similar usage has been followed by HOLZAPFEL, v. ZITTEL and TSCHERNYSCHEW.

We must not, however, overlook the fact that HYATT also introduced a generic term, GEPHYROCERAS, specifying as its type-species the *Gon. sinuosus,* Hall, as illustrated on plate lxx (figs. 73–75) of Palæontology of New York, vol. v, pt. 2. This is an Intumescens-zone fossil which we hold to be specifically the same as *Gon. Pattersoni.* The specimens cited by HYATT, and all of the material which served for the illustration and description of the fossil are casts of macerated shells such as occur commonly in the shales and slabby sandstones of the Naples beds where, by wear before fossilization and modifications during and since that process, apparent umbilication has been greatly increased and angularity of the suture much diminished. A strictly precise construction of this generic term, therefore, leaves *Gon. Pattersoni* its type,

and thus the genus becomes a synonym of the name MANTICOCERAS. Among the other typical species cited by HYATT is the *Gon. Buchi*, de Verneuil,* which is throughout of the *Intumescens* type, most closely approximating the normal of our fauna. The name GEPHYROCERAS has, however, been employed by v. ZITTEL for species of discoidal form, with wide umbilication and peripheral sulcus such as *Gon. calculiformis*, Beyr., which HYATT included in his list of examples, and upon which, it would seem, that the generic definition was largely based. It would probably not be far from the intention of the author of the term to propagate it with this meaning.

MANTICOCERAS PATTERSONI, HALL (sp.).

PLATE I, FIGS. 1–12; PLATE II, FIGS. 1–4, 6; PLATE IV, FIGS. 14–18.

Form of Shell. *The Normal Adult.* In the Naples fauna the predominant form is of moderately large size at maturity and its adult characters are practically assumed with the attainment of an approximately invariable dimension which, under normal conditions, is a width of about 80–100 mm. The shell is sublenticular, with the final whorl laterally compressed; its surface highest close upon the umbilicus where the slope on the final whorl is abrupt and almost vertical to the next inner whorl, and whence it rounds broadly outward with a gently convex curve to the venter, itself narrow but well rounded. The actual contour of the final whorl, of which the chamber of habitation occupies one-half, is progressively changing throughout its length, as we shall have occasion to observe more fully, and this modification consists in the alteration of the form of the conch by the broadening of the lateral slopes, the lessening of their convexity, the narrowing of the venter and the increasing prominence of the lateral angle. The usual form of the whorl in cross-section at the base of the living chamber of the adult has a somewhat sagittate outline.

In this normal form the umbilication is complete, though it is not great either at maturity or in any of the approaching stages. It appears to be an increasingly conspicuous feature as growth advances through the stages of maturity, though the degree of umbilication of the shell is actually decreasing up to maturity. Whatever features, however, are here specified as characterizing epheby must be looked upon as climacteric in their processional acquisition or modification. Variations from the prevailing type have, as we shall observe,

* Trans. Geol. Soc. vol. vi, pl. xxvi, fig. 1 (not fig. 2). 1842.

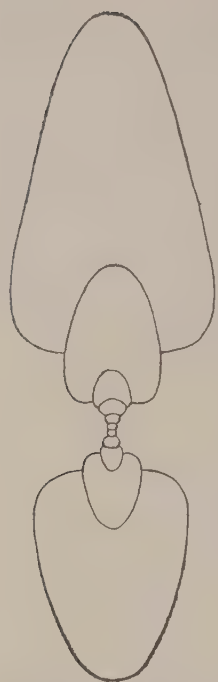


Figure 1. *Manticoceras Pattersoni*, natural size. Vertical section through an adult shell of 5½ volutions, showing the variations in whorl-section and the gradual increase with final decrease of overlap in the whorls.

been interrupted at various stages of acquirement, epheby being sometimes hastened, sometimes delayed. It will be understood that in terming this form normal we do not assume the form thus characterized as a center of departure for variations, but merely as the most commanding expression of the *Intumescens* type in these faunas. It is the *Pattersoni* subtype.

This expression of the species is wide-spread; although it has not been observed in the Styliola limestone or introductory appearance of the fauna, it is found usually with indifferent preservation, scattered abundantly through the greenish and grey shales of the Naples beds, not infrequently finely preserved in the calcareo-argillaceous concretions of these beds, occasionally in full size as barite replacements in concretionary masses. Many fine specimens have been taken from the red and green kramenzel or concretionary stratum which, in my previous papers, has been fully described as the "goniatite concretionary layer." This is a stratum best developed in the northern part of the town of Naples whence it has been followed eastward through some of the townships of Yates county.

The form continued its existence while the sediments of this age gradually became more arenaceous, and its impressions are frequently observed on the sandy flags intercalated among the lower shales of the group. In the upper beds the species is rare. It has been stated above that the shells which have been described as *Gon. sinuosus* and *Gon.* (*Clymenia*) *Nundaia* are all examples of *Mantic. Pattersoni* usually of large, gerontic size, such modifications in septation and umbilication as they present being wholly due to maceration before, destruction during, or distortion since, fossilization.*

The specimens to which these names have been authoritatively applied and which conform in their general aspect to the illustrations and descriptions, have the walls of the shell worn away, the septa also more or less abraded along their lateral portions so that all lobes and saddles are diminished as the section which they expose to the surface is taken near or even along the center of the septum where the convexity and concavity is in all parts greatly

* *Gon. sinuosus* was described by Prof. HALL in 1843 (Rept. Geol. Fourth Dist., p. 243, fig. 6); *Gon.* (*Clymenia*) *Nundaia* by HALL, in 1874 (Descr. New Species of Goniatitidæ, p. 3, the same being reprinted in the Twenty-seventh Ann. Rept. N. Y. State Mus., p. 134, 1875). Both forms were figured under their respective names in the Illustrations of Devonian Fossils (pls. 70 and 72, 1876,) but in 1879 (Pal. N. Y., vol. v, pt. 2, p. 460), the two are regarded as representing one species, *Gon. sinuosus*, which is illustrated on plates lxx, (figs. 13–15), lxxii (fig. 11), lxxiv (fig. 11). The localities from which the species is cited are in the sandstones of the Portage group, in Livingston, Genesee, Chautauqua, Cortland and Tioga counties.

diminished. The great lateral saddle, by this process, becomes often much broadened but less convex, while the lateral and ventro-lateral lobes, the former acute and the latter linguate or sagittate, are likewise broadened and blunted. It is often the case that the ventral lobes are unduly shoved to one side and made to appear as though belonging to the lateral course of the suture. On Plate III, fig. 4, is given an illustration of such a form from the flagstones which, shows to what an extreme the modification from maceration or abrasion of one-half of the shell, may be carried. The lateral lobe is almost obliterated, the ventro-lateral lobe extremely abbreviated, the great lateral saddle notably magnified in width and the ventral lobe turned into the apparent lateral course of the suture. The outline of the septa here is almost a median section of the septum in the *Pattersoni*-type. It is to be added that the thickness of the fossil is but a small fraction of an inch. Its aspect is that of a nautiline goniatite similar to the *Gon. Roemeri*, Holzapfel.*

Manticoceras Pattersoni extends upward in the rock series above the original limit of the Portage group. It is present in the Wiscoy beds, lying above the Portage sandstones and further upward the species is, in rare instances, associated with the rich brachiopod fauna of the Chemung formation. A few specimens collected in the beds of the middle part of the Chemung group, from the quarries at Elmira, Chemung county, are the only ones which have come under my observation, and these show no feature which will justify a separation from the *Pattersoni* type. All are large and some show a gerontic condition in the close crowding of the septa of the final volution.

Abnormals. Another expression of the species is a form which we have designated by the varietal term *styliophilum*, inasmuch as it is the form assumed by *Mant. intumescens* with its earliest appearance in the Styliola limestone. This variation is of persistently smaller size than the normal, seldom exceeding at maturity a diameter of about fifty mm., but at this size it has the section of the body volution in an even more progressed condition than that of the adult *Pattersoni*; that is, while the inner or dorsal slope is abrupt, the broad lateral slopes are at first, near the inner curve, convex and thence ventrally become gently concave, while the venter is bluntly rounded and the slight concavity of the sides gives it a certain degree of prominence. Brief consideration of the figures here given here will be sufficient to demonstrate that this narrow and compressed form of the whorl

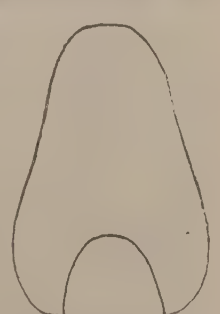


Figure 2. *Manticoceras Pattersoni*, var *styliophilum* Section of final whorl, somewhat enlarged.

*Palaeontographica, XXVIII, III, N. F. iv, pl. 2. (42), fig. 1, from the Intumescens-zone of Westphalia.

would be the natural outcome of a continuation of development beyond the extreme attained by *Mantic. Pattersoni*. *Styliophilum* is, thus, in the form of its whorls, a progressed type. Its sutures, however, are less extreme in the development of lobes and saddles than in *Pattersoni*. In respect to the degree of umbilication there is no appreciable departure from the normal.

This form is undeniably interesting as characterizing the earliest manifestation, in the New York faunas, of the entire *Intumescens* group. The same form very seldom appears in the second manifestation of the fauna. Accompanying the var. *styliophilum* in the prenuncial fauna are two forms to which attention may here be briefly directed: the species *Mantic. contractum* and *Mantic. apprimatum*. Both have the aspect in gross of *Mantic. Pattersoni*, but are both much more closely umbilicated shells, of persistently smaller habit. *Manticoceras contractum* has a very distinct ornamentation, showing upon the late whorls a fasciculation of the striæ into ridges and a convexity of whorls which together (and we have not much else to rely upon thus far in construing the species) separate it pretty widely from the *Intumescens* type. The other, *Mantic. apprimatum*, has a broadly sloping final whorl and, in respect to ornamentation, shows that the elementary period during which the simple, continuous varices were introduced, was of much longer duration than in *Mantic. Pattersoni*, and we find these lamellæ without intercalations extending forward through the third volution; farther indeed than in the species *Mantic. tardum*, where a similar character obtains, accompanied by much greater umbilication than in either *Mantic. Pattersoni* or *Mantic. apprimatum*.

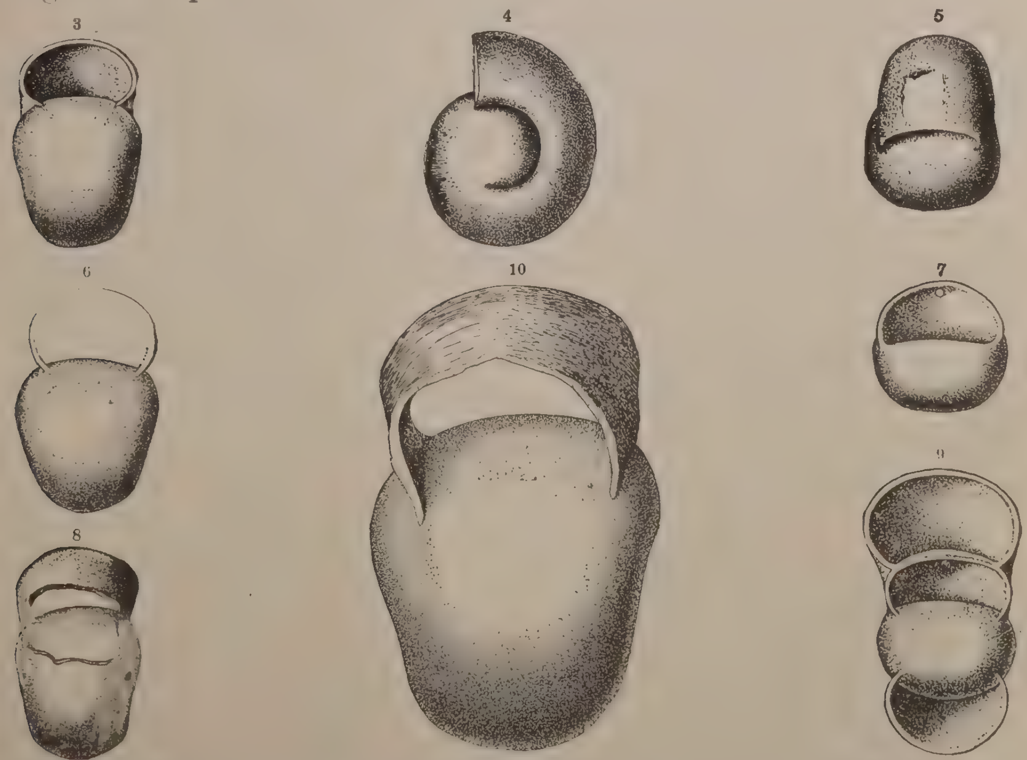
Development of Form. Such observations as are here made in regard to the modification of the shell-form with growth are largely based upon delicate barite replacements of young shells which preserve in marvellous perfection the details of structure and ornament. These specimens, which in many cases represent the entire shell in various stages of early growth, have been derived almost wholly from isolated calcareous concretions in the lower part of the Naples beds about Honeoye lake, in the towns of Richmond and Canadice, Ontario county; a few have been obtained from similar concretions taken farther westward, in Livingston county, about Conesus lake. In the Canandaigua lake valley or westward in Yates county, none have been found in this mode of preservation, and evidences of these young shells are comparatively rare in the shales.

The apparent regional abundance of these young, may be due to their being rendered conspicuous objects by the white or pinkish barite which has replaced the original shell substance, but that they do thus abound and that the observations here put forth are not insufficiently grounded is evinced by

the fact that a single small concretion produced under careful manipulation, 500 of the young of this species alone; together with the young of other species, fully 900 specimens of immature goniatites.

Full grown examples of *Mantic. Pattersoni* are not often found in association with these young shells, but that the latter are of this species is clearly shown by their agreement in all points with young shells obtained by the slow and unhandy process of breaking back the whorls of a mature specimen.

THE PROTOCONCH :— *Shape.* The embryo shell is an inflated sack with a somewhat flattened or depressed distal surface. Its expansion is abrupt, so that its greatest diameter is near, though not at, the distal extremity. This inflation gives to the protoconch a much more considerable diameter than that of the first whorl, as shown in all of our figures. Viewed from its extremity it has a rather narrow, transversely subelliptical outline, while from the opposite side it is somewhat pear shaped, swollen above and contracting below, not regularly but with a rather sudden decrease of convexity just beyond the greatest expansion.



Figures 3-10. Views of the protoconch. Figs. 3, 6, Proximal or ventral aspect, passing into the nepionic shell; Fig. 8, Similar view from opposite side. Figs. 4, 5, Protoconch and nepionic shell from the side and above. Figs. 7, 9, show the distal extremity of protoconch, the latter with attached nepionic whorls. All x 25. Fig. 10, Proximal view, x 50.

Size. In all the specimens measured, the dimensions of this elementary shell are essentially the same, its width at the distal extremity being .8 mm., and its length (dimension at right angles to width) being the same or .8+mm.

In a specimen of *Mantic. intumescens* from the lower upper Devonian limestone at Bredelar, Westphalia, the protoconch appears to be somewhat larger, about .9 mm. in length and its convexity as viewed from the side very great, more pronounced than in any of our specimens. We shall have occasion to direct attention to the fact that, within comparatively restricted limits in these cephalopods, the protoconch varies greatly in form, in minor generic divisions, if not among commonly accepted species of the same genus. Slight variations of form in the protoconch are associated with, and probably in part responsible for wider divergences in the later characters of the shell.

Relative asymmetry of the Protoconch. Repeated observations seem to indicate that the protoconch is asymmetrical, not in itself but with reference to the first whorl of the shell. That is to say, the nepionic shell described a revolution not along, but at a very slight angle to the dorso-ventral axial plane, and one of its convex and protuberant lateral extremities therefore protrudes farther than the other. This may not always be the case, at least in some instances it is difficult of detection, but in the majority of instances examined it is clearly shown. We are not able to state whether this prominence of the protoconch is invariably the greater on a given side, but it thus far appears to be a peculiarity of the dextral side of the shell. A minute inclination of the shell in drawing will obscure or aggravate this asymmetry, and we have, in consequence, redrawn the majority of the figures here presented. It is important to understand that this asymmetry is not inherent in the protoconch, but rather in the direction of revolution at the commencement of the nepionic stage.

Relation of the Protoconch to Umbilication. From the much greater diameter of the protoconch than that of the nepionic whorl it is clear that umbilication was an unavoidable necessity for at least an early period in the life of the species.

PROGRESSIVE MODIFICATION OF FORM. — *The Nepionic Shell.* The nepionic stage of shell growth is clearly delimited. The embryonic condition terminates with the first septum, but this septum is formed before the full reduction of the convexity begun in the protoconch. This is also clearly shown in several of the associated species, *Mantic. nodifer*, *Probeloceras Lutheri*, etc. Thus the expanded portion of the nepionic whorl which bears the second septum, is a determinate fraction of that whorl. The nepionic shell makes slightly more than one-half, sometimes nearly three-fourths of a volution and is characterized by its smooth surface and its slight diameter which at its close is palpably

Figure 11. Side view of protoconch and nepionic shell, showing the broad round varix with which the latter terminates. Taken from a specimen in advanced growth. x 25.

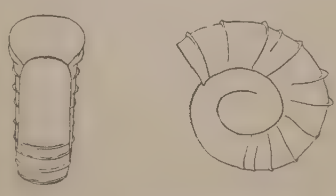
less than that of the protoconch. It is also broader in its surface of attachment to the protoconch. The entire growth of the nepionic shell is not a regular diminution in size, but the least dimensions are attained with the close of the preponderating convexity of the early stage. This is shown in many of our figures where it is seen that the median portion of the nepionic shell is more fully enveloped by the succeeding whorl than any other part of it. The latter part of the nepionic stage is again a condition of increase in size but an increase less rapid than the decrease of the early stage. Thus are defined with unusual lucidity the ana–, meta–, and paranepionic periods of growth. The nepionic period, usually terminated by the introduction of ornamental ribs, is sometimes abruptly ended by an annular swelling as seen in fig. 11.

Figure 12. The protoconch, nepionic and neanic whorls, in an adult specimen of *Manticoceras intumescens*. This specimen is remarkable for the great expansion of the ananepionic shell which is much more pronounced than in *M. Pattersoni*. x 25

Let us now observe that the point at which the form of the conch attains most nearly a circular outline, is in the metanepionic substage; it is, however, only here less broad, not necessarily of more primitive shape than in the ana– and paranepionic conditions. From the earliest period the impressed zone is fully developed and there is no evidence of complete umbilical perforation or entire dissociation of the protoconch from the dorsal wall of the conch.

With the close of the nepionic stage the form of the whorl is transversely subelliptical, its major and minor axes being as 2 to 1.

The form in the Neanic and Ephebic stages. Deferring for the moment any attempt to distinguish the later growth periods of the shell it will be observed from accompanying figures that the proportions of the whorl sections change but little throughout the first three volutions of the shell, which retain a relatively great breadth. The tendency to lateral compression manifests itself somewhat abruptly at the fourth volution, the section becoming obcordate and continuing its form through the fourth and fifth volutions, its length in the fifth volution being one-fifth or one-sixth more than the width. Thereupon sets in the flattening of the lateral slopes and the broadening of the venter accompanied by a great increase in dorso-ventral expansion. A final condition of this tendency is the projecting

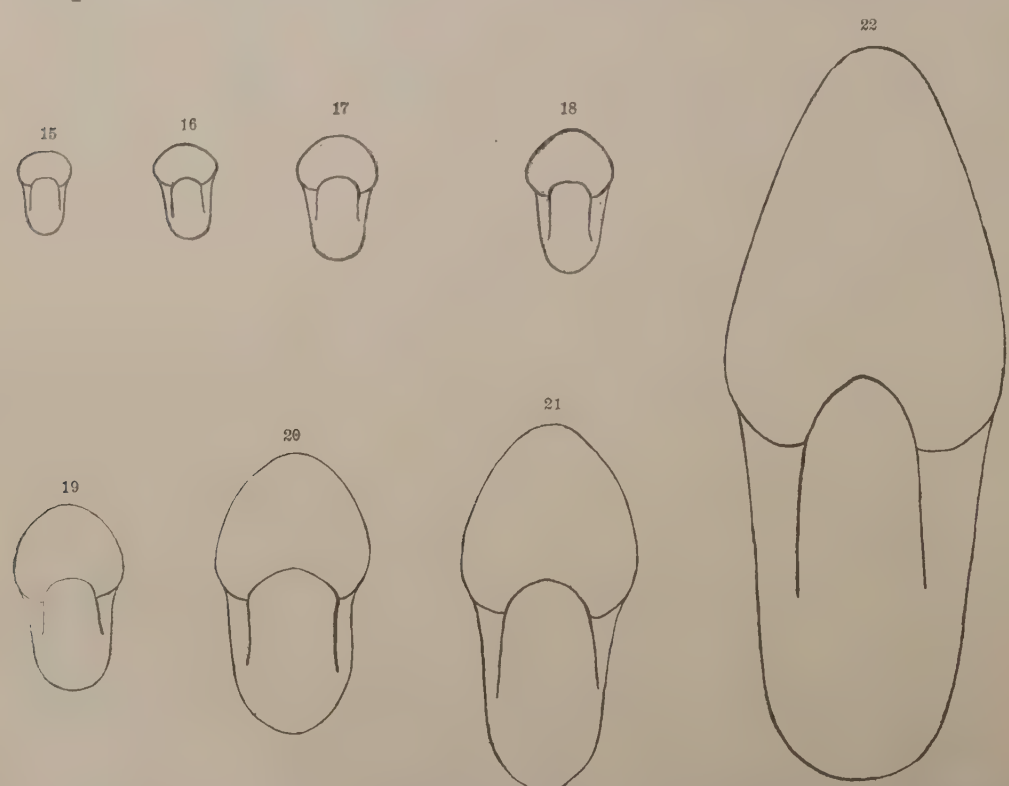


Figures 13, 14. The early neanic shell. x 12.

ventral ridge in ephebic or gerontic stages which is early accompanied by a pronounced recurvature of the ornamental lines, and also the slight incurvature of the lateral slopes, seen in the accelerated ephebic condition of var. *styliophilum*, but not attained in the corresponding condition of *Mantic. Pattersoni.*

Aperture. The progressive changes in the form of the whorl, as just described, express approximately the outline of the aperture in its successive phases. Its actual shape is, however, more accurately delineated by the variations in concentric ornamentation, from which it becomes evident that no trace of the hyponomic sinus appears until the ephebic stage is fairly introduced. It becomes rapidly more pronounced in later growth, and in the parephebic stage is highly developed as a deep retral curve bounded by the sides of the broad carina, which may well be termed the hyponomic ridge.

Umbilication. It has been incidentally remarked that, although the actual size of the umbilicus regularly increases up to the full adult condition of the shell, the degree of umbilication is uniformly decreasing through the same period. Umbilication is due to the failure of each successive volution



Figures 15–22. Front views of entire young shells of *Mantic. Pattersoni*, showing the outline of the whorl section at successive growth phases. All x 4. Fig. 15, 2⅛ volutions ; fig. 16, 2½ vols. ; fig. 17, 2⅝ vols. ; fig. 18, 2¾ vols. ; fig. 19, 3 vols. ; fig. 20, 3¼ vols. ; fig. 21, 3½ vols. ; fig. 22, 4½ vols.

to wholly embrace that preceding; it is measured by the degree to which each whorl is overlapped by that following. We have seen that in the earlier volutions of *Mantic. Pattersoni*, the overlap for the first two or two and one-half volutions is very slight. From the outset the dorsal impressed zone is clearly developed but its increase in depth is very gradual; at first, where the primary whorl is attached to the protoconch, being little more than a surface of apposition. The actual diminution of umbilication with growth can be expressed in terms of the whorl overlapped. Thus in a well developed adult of 6½ volutions it is as follows: at the end of the second volution one-fourth of the dorso-ventral diameter of the whorl is thus overlapped; at the end of the third, three eighths; at the end of the fourth, seven-tenths; half way through the fifth, nineteen-twenty-fourths; at the end of the fifth, seventeen-twenty-sevenths. In other terms expressed approximately; 6.5+, 10−, 18.5, 20.5, 16+. Thus it appears that up to near the completion of the fifth volution there is a gradual increase of overlap or a consequent diminution of umbilication and thence onward the degree of overlap gradually declines and umbilication actually increased. Decrease in umbilication in the forms we have in hand certainly indicates approximation to a phylephebic condition. The very evidence which this species affords demonstrates that gradual loss of umbilication is a process persisting from the ananepionic condition to maturity. It is therefore the gradual assumption of a mature character. The comparatively abrupt reversal of the process, involving an increase in umbilication throughout the course of the very last whorl, may be regarded as coincident with gerontic growth and is evidence of decline; decline not alone of the individual nor of the specific type, but a phyletic result pronounced in well known instances from the early nautiloids to the vanishing expressions of the ammonoids. This evidence of such unwinding in the goniatites, though not striking, is corroborated in the other species here discussed, while in the highly involute forms of *Tornoceras*, especially illustrated by *T. uniangulare*, the umbilication is wholly lost very early and not manifested in any later growth stage.

Ornamentation. We have observed that the assumption of concentric lines of ornament opens the neanic stage of shell growth. Hitherto the shell has been smooth.

The first ornament-lines are relatively strong and distant suberect lamellæ, appearing only over the ventral surface, not extending from one lateral furrow to the other; that is, not encircling the exposed portion of the whorl. Two or three such short lamellæ may introduce the longer ones, and when

these are once developed they occur at subequal intervals and are of equal size, sometimes for an entire volution, sometimes for a less distance. The duration of such subequal lamellæ seems to be a wholly individual character.

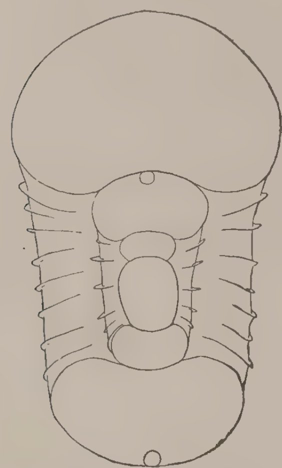


Figure 23. Vertical section of nepionic and neanic whorls. x 10.

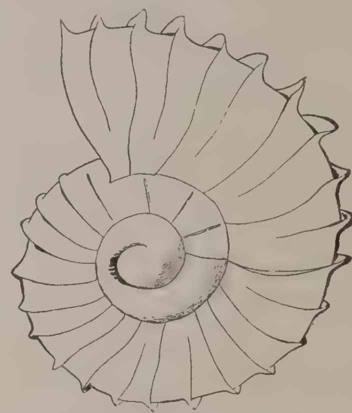


Figure 24. Side view of entire neanic shell, showing protoconch, the swollen ananepionic, contracted paranepionic and expanded metanepionic stages, the abrupt termination of the nepionic stage, the regular, distant and equal varices of the ananeanic stage, followed by the introduction of a subordinate series. x 10.

Yet in all there is a well defined ananeanic substage in which the ornament consists solely of these lamellæ. Upon looking into the umbilicus of a well preserved adult in which portions of all whorls and protoconch are exposed, it will be observed that for one and a half or even two volutions beyond the nepionic shell only such simple and equidistant lamellæ are exposed. This, however, does not mean that only such are present on these younger whorls, for actually, after about a semivolution of ananeanic growth there appear intercalary lamellæ, at first one between each two of the ananeanic or primary series. In this mode the intercalation may proceed with marked regularity for a considerable period, the intercalary lamellæ, at first short and wholly restricted to the venter and ventro-lateral surfaces, become longer and, with the primary lamellæ, extend to the dorsal furrows. After the intercalation has become established it may be continued by the appearance of two secondary lamellæ, and these of equal size. With growth, the secondary interspaces also receive a third set of lamellæ. At the commencement of the third whorl the lamellæ have become of subequal size, relatively crowded, and likewise relatively smaller in comparison with the size of the whorl. In immediately ensuing stages the ornament progressively approximates the character of a simple striation and the full reduction of the lamellæ to this condition is among the characters of epheby.

Tendency to Form Pilae in Gerontic Stages. Old shells, or at least those of a size passing normal adult dimensions, when the exterior is fully preserved, show in occasional instances the gradual assumption of obscure concentric ridges, visible only over the dorso-lateral slopes and having the aspect of low fascicles of fine concentric lines. This tendency is never carried to a notable degree of development, but it is a character of the final growth stages only.

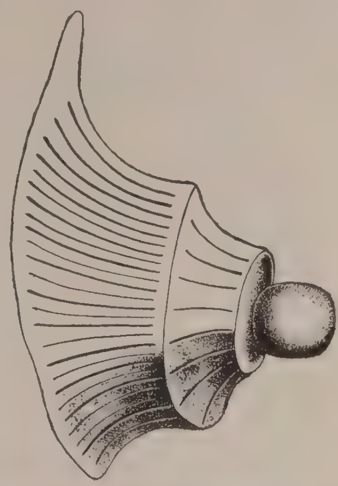


Figure 25. The protoconch viewed from near its distal extremity, attached to an external cast of the early whorls. This specimen shows the smooth surface of the nepionic shell, the simple ornament of the next succeeding whorl and the double series of varices following thereon. x 18.

The precise significance of this superinduced ornament is not clear. While it may be of interest to institute a comparison between it and the duplication or fasciculation of the secondary lamellæ in the neanic stage, it is unwise to attempt the interpretation of one in the light of the other or to regard these pilae as anything else than accompaniments of senility. The gradual development of pilae or their allomorphic expression as nodes is seldom seen among the goniatites, though we may cite a well defined instance in the *Agoniatites expansus*, Vanux. var. *nodiferus*, Hall (See Palaeontology of New York, vol. vii, Suppl. pl. cxxvii, fig. 7).

In the early Styliola fauna, where, as we have already had occasion to observe, the goniatites seem to be in a large degree aggressively accelerated, we find a small form with neanic narrow umbilicus and also neanic whorl section, but with a pilate or subnodate final whorl in which it was perfectly evident that the pilae have originated in the earlier ornament of the surface. This is the species, *Mantic. nodifer*, Clarke.

The hyponomic sinus of the venter is indicated in the late neanic substage by a broad backward sweep of the lamellæ. During ephebic growth this sinus was intensified by gradually narrowing and deeper curvature. In full-growth the now fine, concentric surface-lines are very strongly bent backward and make a deep festoon on the venter, their lateral curvature being so long and the lines on the curve in so close apposition that final growth stages present the appearance of bearing revolving lines at the margins of this hyponomic sinus. These features are seldom well retained as the lines become constantly more obscure with age, but they are shown in some of the accompanying illustrations.

Septation. Septa, the evidences of discontinuous growth, are, in a certain sense, to the interior of the shell what the ornamental varices are to the exterior. In the species under consideration the interval between the septa, constituting the air chambers or loculi, increases outward with some degree of regularity, although relatively to the diameter of the whorl there is a gradual diminution in the depth of these chambers. The statement is, of course, subject to exception especially in senile growth stages and pathologic conditions. The more rapid multiplication of septa in post-ephebic stages has been regarded as one of the normal accompaniments of senility, but it can not be interpreted as a reiteration of infantile conditions. Our observation shows that among the Naples forms of *Mantic. intumescens* this trait is seldom well expressed, sometimes only in the less depth of the last air-chamber. In some of the specimens from the Chemung fauna the crowding of the later septa is a very striking feature. There is sufficient evidence that as far as this specific type is concerned, gerontic multiplication of septa is best displayed in its latest representatives. Attention is directed to a variation hereinafter described as *Mantic. accelerans;* a shell of small size with the *intumescens* suture fully developed but having all the visible air chambers extremely shallow and the septa nearly parallel. It is a form which has been observed in a few instances in the Naples shales, and is to be interpreted as presenting in its septation a prematurely gerontic condition.

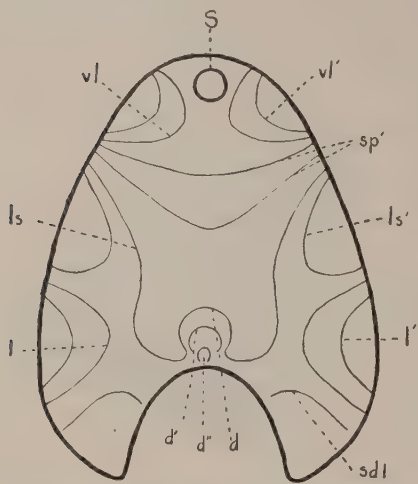


Figure 26. *Manticoceras Pattersoni*, vertical section across an early ephebic whorl showing how the septa may be transected in such a section; *vl* and *vl′*, ventral lobes of successive septa; *sp′*, cut edges of the nearer septum; *ls* and *ls′*, lateral saddles; *l* and *l′*, lateral lobes; *sdl*, subdorso-lateral lobe; *d*, *d′*, *d″*, dorsal lobes of three septa; *S*, sipho.

The diminution in the depth of the air chambers may manifest itself in any part of any individual. It is well represented in the figure upon Plate II (1), which shows a highly irregular crowding of the septa during a considerable portion of the neanic stage of shell growth, and it is to be distinguished from the senile repetition above described, which is the outcome of normal processes, while this desultory manifestation may prove to be pathologic.

The adult suture. The character of the adult suture is expressed in the adjoining figure. Its most striking element is the broad, ear-shaped lateral saddle. On the exposed surface there are two additional saddles, a bluntly

rounded ventro-lateral and a broad partly concealed dorso-lateral. The lobes are three in number, and are all acute; a small median ventral, a long, narrow, sagittiform ventro-lateral and a short and broad lateral.

On the concealed or dorsal surface of the shell there are two lobes and one saddle for each half of the whorl; a long, acute, median dorsal lobe, a short, broadly rounded, subdorso-lateral lobe, and a broad, obtuse dorsal saddle.

Figure 27. *Manticoceras Pattersoni.* The outer course of the sutures in a normal adult.

Development of Form of Sutures: First Septum. The suture of the first septum is a simple curve, showing a well defined median ventral lobe. This is subacute, but the lateral divisions of the suture do not actually come into contact on the ventral surface as in ephebic conditions; from which we may infer the absolutely ventral site and attached condition of the sipho.

The lateral direction of the suture is almost transverse to the dorsal furrow, where it bends gently forward. On the dorsal side the suture makes but a single curvature and that is median, the lobe thus formed being more acute than that on the ventral surface.

Second Septum. The curvature of the second septum is not greatly unlike that of the first, the difference being in the lateral curvature which now tends outward or forward and thus originating the broad ventro-lateral lobe of neanic growth.

Other Pre-ephebic Sutures. The progress in the development of the suture consists (*a*) in a great widening of the ventral lobe, (*b*) in the pushing forward of the lateral curve into a broad lateral saddle, (*c*) the development of a dorso-lateral lobe; this is a condition shown at 2 volutions.* At $2\frac{1}{3}$ volutions the broad ventral lobe still obtains, the lateral saddle is narrower and more prominent, the dorso-lateral lobe much broader than before and rounded.

Appearance of the Ventral Lobe, Ventro-lateral Saddle, Subdorso-lateral Lobe and Dorsal Saddle. The first of these lobes, which is so conspicuous as character of maturity, makes its appearance at about the end of the third volution. The form of the suture at 3 volutions, as here represented, shows

* Volutions are counted, in this paper, from the proximal extremity of the protoconch.

that the hitherto broad ventral lobe is divided by a low, sharp angle directed backward and which forms at the same time a ventro-lateral lobe and a ventral saddle of equal size. The introduction of this modification is not accompanied by any other change on the external suture, but concomitant with it is a crenulation of the heretofore simple dorsal suture producing the dorsal saddle and subdorso-lateral lobe. All of our evidence points to the fact that this radical modification in the course of the suture commences simultaneously and, as during its remaining history no important further change occurs, it must be regarded as making the commencement of a distinctive growth period. We shall presently observe that the new departure in this structural feature is contemporaneous with modifications in other differentials. During the later progress of the suture its form is progressively modified by the rapid increase in size, i. e. length of the ventro-lateral lobe, which in the adult is long, acute with slightly convex sides, having a lanceolate outline. The great lateral saddle grows proportionally larger, shows more and more distinctly its characteristic inclination toward the umbilicus and in its ultimate stage its outer or convex curve develops a shouldered appearance.

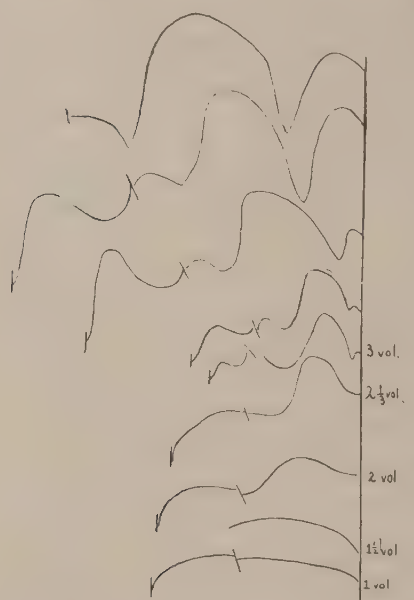


Figure 28. *Manticoceras Pattersoni.* The course of the sutures from the ananepionic shell to maturity.

The lateral lobe gradually narrows, maintains its rounded extremity, even into the anephebic substage, in which condition the suture has throughout the character of that of *Mantic. simulator.* This lobe is angled in normal mature conditions.

Contour of Septa. The first septum is evenly concave outwardly, with an abrupt increase about the sipho. With growth, ultimately this concavity, though not wholly lost, is greatly modified by the multiplication of lobes and saddles on all margins. A section along the plane of coiling will give a series of septal lines in which the earlier have a pronounced convexity throughout, but this is gradually encroached upon by a concavity above, between the ventro-lateral lobes, and another below at the long dorsal lobe.

Sipho. Traces of the inceptive portion of the sipho are clearly retained on some pyrite internal casts of the protoconch. The extent of this caecal tube is evidently considerable and its ventral position very distinctly indicated.

CORRELATION OF GROWTH-STAGES AS EVINCED BY VARIOUS DIFFERENTIALS OF THE SHELL.

ges.		Form.	Umbilication.	Ornamentation.	Septation.
bryonic		PROTOCONCH.			
ionic	Ananepionic	Conch broad, progressively tapering in section.	(*a*)	Smooth in all substages, with terminal varix	First septum straight, with distinct ventral lobe.
	Metanepionic	Conch section contracted.	Abruptly increased.		Second septum with inception of lateral saddle, progressively increased to end of stage.
	Paranepionic	Conch section expanding, terminating in a ridge or varix.	Again decreased but not to (*a*).		
nic	Ananeanic	Gradual progress in contour from a broad subcrescentic section to an obcordate section.	Constant decrease of umbilication by increasing degree of embracement of successive whorls. This decrease is a constantly diminishing quantity.	Very strong, simple varices crossing whorl without curve.	Continuation of development, increasing size of lateral saddles but without introduction of new lobes or saddles.
	Metaneanic			Varices in double or compound series, a primary and one or more secondary, crossing the whorl without curve.	
	Paraneanic			Varices much reduced and all of same size with broad hyponomic curve.	
ebic	Anephebic	In late ephebic conditions with increasingly less convex lateral slopes, and broader, more conspicuous ventral ridge.		Increasing incurvature of hyponomic sinus.	Introduction of ventral lobe, ventro-lateral saddle, dorsal saddle, subdorso-lateral lobe.
	Metephebic		Change from loss to gain in umbilication which is maintained through later ephebic and probably gerontic stages.	Varices reduced to lines showing a tendency to gather in fasicles which may take the form of low pilae.	Progressive increase in lobes and saddles, continued bluntness of lateral lobe. *M. simulator* stage.
	Parephebic				Normal adult characters with acuteness of lateral lobes.
ontic	Anagerontic	The sides of the whorl distinctly concave and ventral ridge pronounced; carinate in tachygenic species, *M. oxy*, *M. vagans*.			Lateral enlargement of lateral saddle producing a shouldered appearance. Septa parallel and crowded in tachygenic forms: *M. accelerans*.
	Metagerontic				
	Paragerontic				

At the first septum and those immediately following, the siphonal collar lies close upon the inner shell surface as indicated by the absence of any line of union between the sipho itself and the wall of the shell. This interspace which is noticeable in the earliest stages gradually becomes obliterated and in early neanic conditions the suture-line is uninterrupted.

Following are more precise bibliographic reference lists of the variations of the Intumescens type mentioned in the foregoing discussion.

Manticoceras Pattersoni, Hall (sp.), 1860.

1843 *Goniatites sinuosus*, Hall. Geology of New York, Rept. Fourth Dist., p. 244, fig. 6 (p. 243); p. 245, fig. 9. The originals are very incomplete examples, in themselves insufficient to give definition to the species. One of the specimens is from the shales on Cashaqua creek. It is also stated to occur on the lake Erie shore.

1860 *Goniatites Patersoni*,* Hall. Thirteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 99, figs. 9, 10. The fragment which served as the original of the species shows the characteristic septa. It is stated to have been obtained from the shales on Patterson's creek, Livingston county. This is a locality of the lower Portage shales.

1875 *Goniatites Pattersoni*, Hall. Twenty-seventh Ann. Rept. N. Y. State Mus. Nat. Hist., p. 136. The species is mentioned in a list as occurring in the Portage and Chemung groups.

1875 *Goniatites* (*Clymenia?*) *Nundaia*, Hall. Twenty-seventh Ann. Rept. N. Y. State Mus. Nat. Hist., p. 134. (Also in the same paper published 1874, in advance of this report.) This form is here set off as distinct from *Gon. sinuosus.* With regard to this proposed name, Prof. Hall subsequently wrote: "The *Gon. sinuosus* as originally illustrated in the *Geolog. Surv. of N. Y., Rept. of Fourth Dist.*, included two very distinct species. In order to rectify this error, I published, in 1874, a description of *G. Nundaia,* recognizing the species as being in part those forms which had before been included under *G. sinuosus.* By this rectification it was intended to leave the form figured on page 245 of the *Geological Report* as the representative of *G. sinuosus.* The condition of preservation of the original specimen is such as to preclude a critical examination of the septa and other important characters, while its form and external aspect are so nearly similar to *G. discoideus* that I am induced to

*This is the original spelling of the name. Professor HALL, however, informs me that the specific name was given as a mark of respect to the Hon. GEORGE W. PATTERSON, Lieutenant Governor of the State in 1848.

unite the two as one species. The appearance of an umbilicus in the original figure is due to some adhering stone upon that part of the shell." (Palaeont. N. Y., vol. v, pt. 2, p. 462.)

1876 Illustrations of Devonian Fossils. See references under 1879, Palaeont. N. Y., vol. v, pt. 2.

1879 *Goniatites sinuosus*, Hall, Palaeontology of New York, vol. v, pt. 2, pp. 460–463, pls. lxx, figs. 13–15; lxxii, fig. 11; lxxiv, fig. 11. Figures 13 and 15 of plate lxx are of macerated specimens somewhat restored in drawing. Abrasion has modified the form of the sutures. Those shown in the specimen represented in fig. 14 are immature septa of *Gon. Pattersoni.*

Goniatites Pattersoni, Hall, *op. cit.* pp. 464–467, pls. lxii, figs. 1–5; lxxiv, fig. 15.

Goniatites complanatus, Hall, pl. lxx, fig. 9 (8 ??).

1883 *Manticoceras Pattersoni*, Hyatt, Proc. Boston Soc. Nat. Hist. vol. xxii, p. 318. This species is here mentioned among the representatives of the proposed genus MANTICOCERAS.

1885 *Goniatites Pattersoni*, Clarke, Bull. U. S. Geol. Surv. No. 16, p. 48.

Goniatites sinuosus, Clarke, *op. cit.* p. 49.

1891 *Goniatites intumescens*, Clarke, Neues Jahrb. für Mineral. Bnd. 1, p. 166.

Goniatites sinuosus, Clarke, *loc. cit.*

Goniatites sp. nov. (a). Clarke, *loc. cit.*

Goniatites sp. nov. (d). Clarke, *loc. cit.*

1891 *Goniatites intumescens* Clarke, American Geologist, Aug. p. 93.

Goniatites sp. nov. Clarke, *loc. cit.*

Goniatites sp. Clarke, *loc. cit.*

(*G. sinuosus* Clarke, p. 94: "Specimens of *Gon. intumescens* which have been exposed to weathering since fossilization or maceration before it, often exhibit peculiar modifications of the septa. The specimens found in the thin sandy layers or flags are usually thus modified and in some of their conditions are similar both in exterior and septum to those which have been described as *G. sinuosus* and *G. nundaius.* I am at present inclined to believe that *G. sinuosus* is only a condition of *G. intumescens* resulting from modification by mechanical and post-vital influences.")

1892 *Goniatites intumescens* Clarke, Amer. Jour. Science, vol. xliii, p. 57.

1893 *Goniatites intumescens* Clarke, American Geologist, vol. xii, p. 113.

GENERAL OBSERVATIONS.

The species *Manticoceras Pattersoni* has now been quite fully described. We may here briefly call attention to its nearest allies in other representations of the Intumescens-fauna.

The specimen originally used in illustration of BEYRICH's description of *Gon. intumescens** is of medium size with broad final whorl having convex lateral slopes.

The shell described as *Gon. orbiculus*† is of considerably smaller size and closer umbilication. The course of its suture indicates immature or phylonepionic growth and the shell has usually been regarded by later authors as identical with *Mantic. intumescens.*

In the elaborate illustration of the goniatites given by G. and F. SANDBERGER ‡ is presented the general range of variation in form of *Mantic. intumescens* and its allies. In regard to these it may be remarked that the essentially adult conditions represented on pl. vii, show a greater breadth of body-whorl § than we meet with in the American species.

With reference to the adult *Mantic. Pattersoni*, such forms, of themselves fully adult, are delayed, but the later narrowing of the whorl is indicated in specimens represented in figs. 2c and e.

A closer approximation to the *Pattersoni*-type in whorl section is the *Gon. lamellosus* Sandb. (pl. viii, figs. 1, a–e), founded on shells which happened to retain the external surface and show a strong development of the hyponomic curve in the striæ. The figures, however, represent this curve as delimited by actually continuous revolving lines which never, to our observation occur in *Mantic. intumescens.* How many of the SANDBERGERS' little species with immature *intumescens* sutures are to be construed as worthy of specific recognition it is not wholly safe to say, but there seems no good reason for doubting that *Gon. lamed.* var *rugosus* (pl. viii, figs. 4a–e), *Gon. lamed.* var. *complanatus* (ditto, figs. 5a–d) and *Gon. lamed.* var. *cordatus* are undeveloped forms of *intumescens* or stand in such a phyletic relation to that species.‖

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* Beitr. zur Kenntn. der Verstein. der Rhein. Uebergangs-geb., p. 36, pl. ii, figs. 3a–c. 1837.

† *Loc. cit.*, p. 36, pl. ii, figs. 4a–b.

‡ Verstein. des Rhein. Schicht-Syst. in Nassau. 1856.

§ The large shell, sharply carinate through the final volution (figs. 1a, b) we exclude from this species, following HOLZAPFEL and others. Though with the *intumescens* suture, it evinces too extreme acceleration in the acquirement of this ultimate gerontic trait to be properly included within the specific limits of *Mant. intumescens.* The same remark applies to the *Gon. intumescens* figured by F. ROEMER in "Lethaea Palaeozoica" (pl. 35, fig. 10a, b), and the *Gon. Hoeninghausi* (not v. BUCH), figured by D'ARCHIAC and DE VERNEUIL (Descr. Foss. Older Deposits Rhen. Prov., p. 337, pl. xxv, figs. 7 a, b. 1842). Regarding such forms as corresponding to possible, though not observed gerontic conditions of *Mantic. intumescens*, we have described a similar large, acutely carinate shell from the Portage upper flags as *Manticoceras oxy.*

‖ By FOORD and CRICK (Cat. Fossil Cephalopoda Brit. Mus. Part iii, 1897), the first of these is identified with *Gephyroceras* (= *Manticoceras*) *intumescens*, the second is recognized as *Gephyr. complanatum*, while the third is referred to *Gephyr. orbiculus*, Beyr.

The form which was described by D'ARCHIAC and DE VERNEUIL as *Gon. Buchi* * approaches most nearly to the normal adult condition of *Mantic. Pattersoni*, though with somewhat more numerous septa on the final whorl.

The specimens described by TSCHERNYSCHEW † are also directly comparable to the American forms in the attainment by growth of the narrow, subcarinate final whorl of fully matured shells from the broadly obcordate whorl of earlier growth.

Distribution of Manticoceras Pattersoni.

Portage group. The species occurs in notable abundance in a layer of red and green kramenzel or nodular silico-argillaceous limestone lying about 200 feet above the top of the Genesee shales in the Naples section. The rock is best developed in Parrish gully, on the east side of the Naples valley, and appears at various points on the west side. It has been traced by Mr. D. D. LUTHER as far eastward as Branchport, on Keuka lake (Bellknap's gully, one mile north of village), but is not continued far toward the west. The fossil is found in the shales and on the surface of flags, but not often with favorable preservation. Excellent specimens are often obtainable in the larger concretions in which certain of the lower shale beds abound and is commonly seen in the gullies and ravines on Conesus lake and eastward on Hemlock and Honeoye lakes, in various sections throughout Livingston and Ontario counties, in Genesee county at Attica, Sonyea and along Cashaqua creek.

Chemung group. Specimens have been found in these rocks at Elmira, Chemung county, and Pine Valley, Schuyler county.

MANTICOCERAS APPRIMATUM, sp. nov.

Plate VI, Figs. 27–29.

We may best indicate the characters of this well defined form by comparison with allied species. The shell appears to be of uniformly small size at epheby, and the final whorl has, in late growth stages, the low, broad lateral slope of *Mantic. Pattersoni*, though not becoming concave on the sides as in the var. *styliophilum*. The umbilication is deep and narrow, closer than in any other species, even more extreme than in *Mantic. contractum*. The

* Desc. Foss. Older Deposits Rhenish Prov. p. 40, pl. xxvi, figs. 1 a, b, 1842. This was shown by KAYSER (Zeitsch. der Deutsch. Geol. Gesellsch. 1893, p. 646) to be synonymous with *Gon. intumescens* and it was proposed by him to apply the term *Buchi* to the French authors' *Gon. Buchi*, var., in which he is followed by HOLZAPFEL (Palaeontographica N. F. viii, 6, (xxviii), p. 243 [19]). The SANDBERGERS (*op. cit.*) and CLARKE (Fauna des Iberg. Kalk.. p. 326, 1884) have adopted the older term of STEININGER, *Gon. serratus*.

† Fauna des mittl. und ober. Dev. am Westabhange des Urals. pl. II, figs. 3, 5, 1887.

ornamentation, likewise, is extreme in its simplicity; simple varices are introduced at the close of the smooth larval stages, and are continued in their simplicity for a much longer period than in any other form, not exceeding even *Mantic. tardum*. We find them throughout the extent of the third whorl, and thereafter they seem to become obsolescent without modification. As to septation, the adult whorls here, as in *Mantic. fasciculatum*, *Mantic. tardum*, etc., indicate a condition immature in the Intumescens type.

Manticoceras apprimatum occurs in the Styliola limestone of Middlesex and in the Naples beds of Naples; it has also been found near Griswolds, Wyoming county. It is not of frequent occurrence.

MANTICOCERAS TARDUM, sp. nov.

Plate I, Fig. 13; Plate VI, Fig. 31.

The early whorls of this species are highly ornate and the elevated concentric striæ, commencing at the close of the smooth nepionic condition, come in singly during the early neanic stage, just as in *Mantic. Pattersoni* and *Mantic. apprimatum*, but while these varices very soon thereafter become increased by intercalation in *Mantic. Pattersoni*, they do not so multiply in *Mantic. tardum*, but this primitive expression of single, simple, distant lamellæ extending fully about the whorl to the umbilicus, is maintained to the completion of the third volution very much as in *Mantic. apprimatum*. During the fourth volution subsidary striæ are very gradually introduced, but these are very faint and do not greatly obscure the general regular effect of the ornament. Over this whorl the entire surface marking becomes more and more faint. This peculiar character of the ornament is distinctly primitive with reference to *Mantic. Pattersoni* and *Mantic. fasciculatum* and essentially parallel to it, somewhat in advance of *Mantic. apprimatum*. Indeed we may say that in respect to this feature only, these forms stand in the following progressive relation: *Mantic. apprimatum*, *Mantic. tardum*, *Mantic Pattersoni*, *Mantic. fasciculatum*.

The umbilication of *Mantic. tardum* is much greater than that of *Mantic. Pattersoni* and *Mantic. apprimatum*, while equaling that of *Mantic. fasciculatum*. The form and cross-section of the whorl is distinct from both of these at parallel growth-stages, being broader and flatter on the venter, but in no case do the specimens indicate a ventral keel or hyponomic sinus.

The suture is not clearly displayed in the specimens examined, but enough is shown to indicate that on the fourth whorl a distinctly manticoceran character has been assumed. Entire immature shells similar to that shown in our figures have been seen in several instances, retaining the aperture unbroken and showing the stomal callous and resorption of varices.

The species occurs in the lower Portage shales of the Briggs gully, Honeoye lake.

MANTICOCERAS SIMULATOR, Hall (sp).

Plate I, fig. 14.

1875 *Goniatites simulator*, Hall. Twenty-seventh Ann. Rept. N. Y. State Mus. Nat. Hist., p. 133 (also published separately in advance, 1874).

1876 *Goniatites simulator*, Hall. Illustr. Devon. Fossils, pl. lxix, figs. 1, 2.

1879 *Goniatites simulator*, Hall. Palaeontology of N. Y., vol. v, pt. 2, p. 453, pl. lxix, figs. 1. 2; pl. lxxiv, fig. 8.

Reference has already been made to the fact that this form, known only from a single specimen, stands in a definite relation to the normal of *Pattersoni*. Its size indicates maturity, while its suture shows, in its rounded lateral lobe, positive evidence of immaturity. This character is supplemented by the whorl-section which is somewhat broader than in the normal ephebic type.

Figure 29. *Manticoceras simulator*. Adult suture.

It is from beds containing *Liorhynchus* at or near Ithaca, N. Y.

This species is one which may be directly compared with such European Intumescens-zone forms as *Gon. carinatus* (Sandberger, not Beyrich), as identified by TSCHERNYSCHEW* and by HOLZAPFEL.† The typical *carinatus*, however, has actually carinated whorls, but HOLZAPFEL states that the shells from Martenberg (Westphalia) referred by him to this species show evidence of the feature with extreme rarity, and never clearly. This author lays principal emphasis on the course of the suture as a distinguishing mark from *Mantic. intumescens*. If, however, we go back to BEYRICH's original we find that the keel is a well developed feature on the entire final whorl, or at least on what is represented as such. The figured specimen is, also, quite small and closely umbilicated. If the entire shell is not represented in this figure we should be

* Fauna des mittl. und ober. Devon am West Abhange des Urals, pl. 2, figs. 1a–c, 1877.

† Palæontographica, *loc. cit.*, p. 242 (18).

constrained to assume, for reasons already stated, that further growth would have intensified rather than have lessened the carination of the whorl. This is a feature which would place the shell at a different stage of progress than such forms as our *Mantic. simulator*, the SANDBERGERS' and TSCHERNYSCHEW's *Gon. carinatus.*

MANTICOCERAS RHYNCHOSTOMA, sp. nov.

Plate IV, Figs. 6–13; Plate V.

The Adult. We have found that in *Mantic. Pattersoni* the ephebic conditions accompany an approximation to dimensions which are well represented by the figures given on Plate I, and embody from five to six volutions of the shell. There are, naturally, slight individual variations in size of shells at any given growth period, but it is apparent that in *Mantic. rhynchostoma* the size of the shell at any definite number of volutions is greater than in *Mantic. Pattersoni*; hence, the shell of the former at the average adult dimensions of the latter, presents fewer volutions than that. In the general aspect of the two however, even close inspection of the exterior will usually fail as a basis of distinction, but attention may be directed to the following facts: in *Mantic. rhynchostoma* the lateral slopes of the conch are more convex and the venter is sharper at its periphery though considerably broader just within this curve. These are but slight distinctions nor are they supplemented in any degree either by the character of septation or the nature of umbilication at such growth stages. Let, now, vertical sections be made through the umbilicus of such equi-sized specimens and their fundamental difference is emphatically declared.

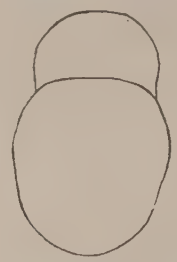
Figure 30. Suture of *Manticoceras rhynchostoma* at the fourth volution.

The Protoconch: Immature Phases. The protoconch in *Mantic. rhynchostoma* presents no features by which it can, when isolated, be distinguished from that of *Mantic Pattersoni.* On a comparison of the figures here given this is sufficiently evident without further comment.

The Nepionic Stage. Here we meet with the same smooth condition of the conch extending for rather more than a half volution and terminating in a rounded varix. The phases of the nepionic stage which have already been noted as defining the ana–, meta–, and paranepionic conditions in *Mantic. Pattersoni* are as clearly marked here.

Post-nepionic Stages. With the close of the nepionic condition the differences from *Mantic. Pattersoni* make themselves evident. The varices

which, in the latter, are strong, distant and simple at the beginning, are here lower and closely crowded together. Their arrangement, also, shows a much



Figures 31, 32. Protoconch and nepionic shell of *Manticoceras rhynchostoma*. x 25.

more general variation than has been observed in *Mantic. Pattersoni*. Thus the very close crowding of these varical lines may begin directly with the opening of the neanic period, or may again, be delayed until this

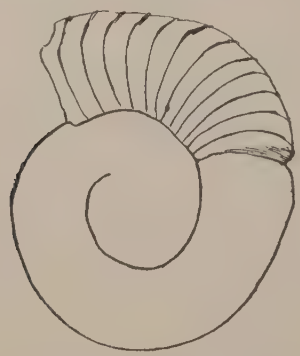


Figure 33. ***Manticoceras rhynchostoma.*** Side view of protoconch, nepionic shell and part of neanic shell. x 25.

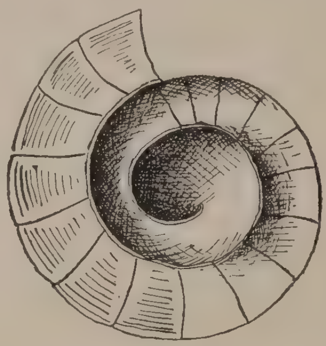


Figure 34. ***Manticoceras rhynchostoma.*** Side view of external cast, showing protoconch, nepionic and prolonged ananeanic growth. x 25.

phase has progressed to some degree. Intercalary lines may or may not appear in the course of the first two volutions, but whether or not there, the surface during this growth is closely and evenly striated.

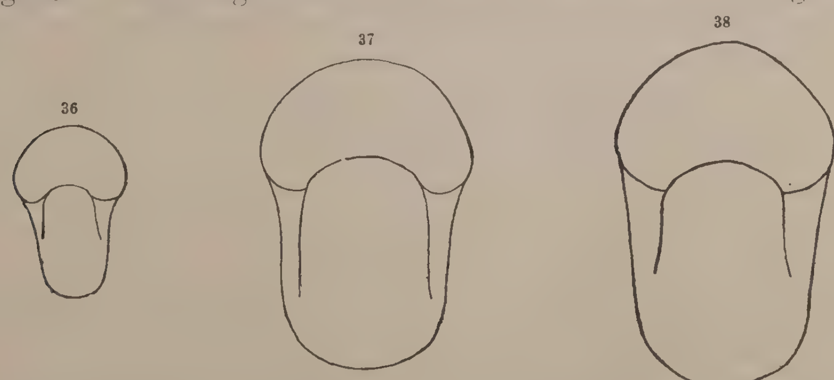
From the commencement of the fourth volution, the surface lines have become so broadened as to appear only as flat, low festoons more elevated at the umbilical margin than elsewhere but, except here, very nearly obsolete.

At their first appearance the varices of the neanic shell are direct, without medial curvature, but by the beginning of the second volution a hyponomic curve is distinctly developed and in subsequent stages is much more pronounced than in the corresponding volutions of *Mantic. Pattersoni*. Notwithstanding the obscurity of the concentric lines after the opening of the fourth volution, the hyponomic sinus is seen to have been prominently developed at this growth stage.

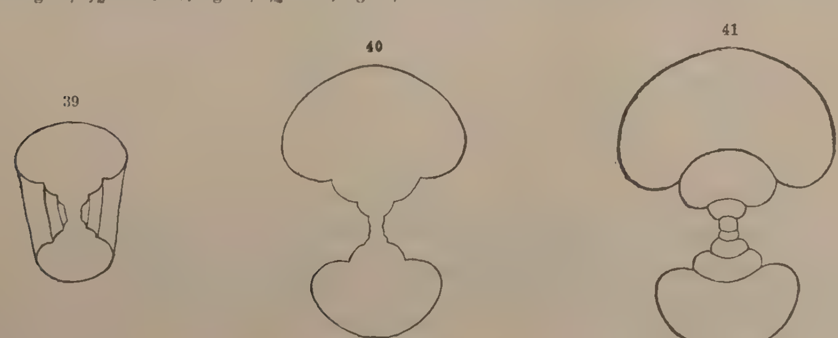
Conch section. It is in this respect that the differences are still more emphasized. At the commencement of the nepionic stage the whorl section in both forms is the same, but thereafter there is in *Mantic. Pattersoni* a marked tachygenic narrowing of the whorl so that at any given point in the length of the conch or at any volution, the conch section of that species is distinctly more sagittate or elongate-obcordate than in *Mantic. rhynchostoma.* This fact it is not necessary to exemplify with statistical measurements; the accompanying cuts serve to show it with sufficient clearness. Notwithstanding the greater breadth of whorl in *Mantic. rhynchostoma,* there is, in the mature condition, as just observed, a more direct lateral slope and a more pronounced ventral margin, the maximum width of the whorl being shown at the umbilical edge.

Figure 35. The early neanic varices. x 25.

The Gerontic Stage. We have already observed that in *Mantic. Pattersoni* the progressive narrowing of the whorl section eventuates in a slight depres-



Figures 36–38. *Manticoceras rhynchostoma.* Outlines of young shells, viewed from in front. x 4. Fig. 36, 3½ volutions; fig. 37, 3¾ vols.; fig. 38, 4 vols.



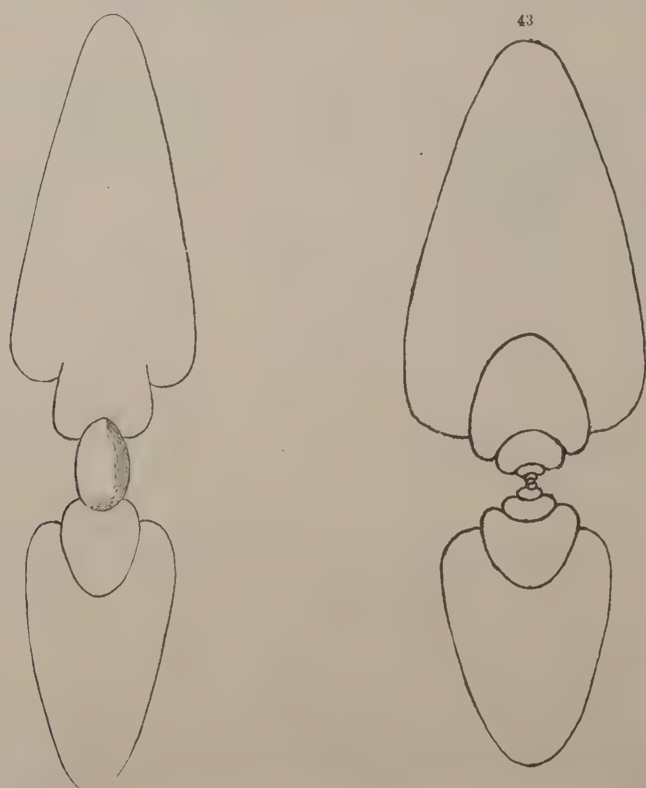
Figures 39–41. *Manticoceras rhynchostoma.* Vertical sections of the early whorls. x 4.

sion of the lateral slopes and the projection of the venter. This venter itself becomes narrower and sharper with increasing age, and it is reasonably prob-

able that in senile stages it becomes acute, so that the outcome would be large carinate shells, such as *Mantic. oxy.* In this series, however, we lack the connecting links and the necessary stratigraphic evidence to demonstrate the unity of the two forms.

It is, to us, more than merely strange that in all our long experience in the acquisition of specimens of this species no large gerontic shells have been met with which can be assigned without reservation to *Mantic. Pattersoni.* With *Mantic. rhynchostoma* the case is otherwise. The concretion-bearing strata along the lake Erie shore in the vicinity of the village of Angola have produced a number of gerontic individuals of great size and excellent preservation. The largest of these measures one foot in diameter, and is more than ordinarily notable for the fact that it displays the apertural margin of the shell without defect. By reference to the figure of this specimen given upon Plate V, the

42 43



Figures 42, 43. ***Manticoceras rhynchostoma.*** **Fig. 42, a senile individual of 6½ volutions, broken through the center, the inner whorls remaining unfractured, showing the rapid narrowing of the final whorl. This figure is one-third the natural size of the specimen. Fig. 43, vertical section of an adult, natural size.**

remarkable character of this aperture will be seen. A pair of broad sagittate lappets extend forward from the lower lateral slopes, terminating in acute points. Above them is a low incurvature of the margin to the venter and at

the venter itself there is a short projecting extension. Thus the curves of the margin have almost no correspondence with growth lines on the body of the whorl.

We look upon this peculiarly conformed aperture, so unusual among the goniatites and so often duplicated among the ammonites, as a distinctly emphasized gerontic character. There can be no doubt that in earlier and in mature stages the aperture does conform in outline to the concentric growth lines, and here likewise, up to within a very short distance from the aperture itself, this conformity must have existed; but beyond this point, with the actual completion of growth this remarkable departure is presented. That this condition, involving the filling up of the hyponomic sinus and the complete alteration of the lateral curves, had existed for but a brief period is sufficiently shown by the fact that growth-lines actually concentric to the aperture are most obscure and traceable only for a little way from the margin.

These large specimens being from six, to six and one-half volutions, show an increasing narrowing of the venter without tendency toward carination, and abruptly sloping lateral surfaces. That they represent the shell, *Mantic. rhynchostoma*, is demonstrated by several specimens which have been diametrically parted through the umbilicus and display the succession of fat whorls characterizing this paraphrase. The sectional figure given on p. 68 (fig. 42) is taken from the same specimen as that figured in Plate V, the inner whorls being retained in their fulness.

Comparison of the aperture in this specimen with the fragment of the carinate body-whorl of *Mantic. oxy*, in which a part of the apertural outline is retained, will show distinct differences. The latter possessed broad lateral ears, but these seem to have been rounded and not acute. They were, also, situated considerably further up on the side of the whorl, and nearly correspond with the curves of the concentric pilae.

MANTICOCERAS CONTRACTUM, sp. nov.

Plate VI, figs. 1, 2.

In adult condition these shells are of relatively small size, very closely umbilicated and the whorls have a longer and more convex lateral slope than *Mantic. Pattersoni*. These features serve to distinguish the species without closer scrutiny.

The protoconch and nepionic stages are as in *Mantic. Pattersoni*. Simple ornamental varices are then abruptly introduced over the whorls, but

these continue for a very short distance only, not more than one-third of a volution, when there directly becomes manifest a difference in prominence and a tendency to group in twos of equal size, with minor intercalations. Thus, when one volution of neanic growth is completed there is a pronounced difference in the varices, and though thereafter on later whorls these lamellæ evince a tendency to become diffuse, yet their grouping into fascicles is continued to maturity and on the mature whorl produces a modification in the contour of the conch, so that the umbilical edge of the whorl is palpably nodose, though the striae, at this phase, are of subequal size. In the third whorl a ventral or hyponomic flattening is very well defined, and though it at no time materially affects the contour of the whorl, it is rendered quite conspicuous by the course of the surface striae. As shown in our figures, the apertural and hyponomic curvatures of these lines are very decided in the anephebic condition. At full maturity, the ventral flattening is obsolescent and the curvature of the striae notably straightened, leaving us to infer a considerable modification in the outline of the aperture of the conch at this stage.

Figure 44. *Manticoceras contractum.* Vertical section showing contour of whorls.

This species is not of very common occurrence and has been observed only in the Styliola limestone, on Canandaigua lake. Its differences from other species of MANTICOCERAS here described may be thus expressed:

Manticoceras apprimatum, of the same prenuncial fauna, is likewise closely umbilicated, the ornament at its introduction is of the same character, but remains simple both in the primary stage, and so far as it has been traced; the final whorls are broader, with a depressed rather than a convex curve, similar in this respect to *Mantic. Pattersoni* var. *styliophilum*. *Manticoceras fasciculatum*, of the same fauna, passes through similar early stages in the development of its ornamentation, but its varices are definitely duplicate for a longer period; its umbilication is much greater and its whorls broad and primitive in their expression. *Manticoceras tardum*, is broadly umbilicated like the last named species, and the simplicity of its ornament is maintained until an early ephebic stage. In *Mantic. Pattersoni*, there is greater umbilication accompanied by a much simpler introduction of the varices, and a distinct whorl section.

MANTICOCERAS FASCICULATUM, sp. nov.

Plate VI, Figs. 13–22.

This is another clearly distinct species whose immature stages are very fully known, while its adult or ultimate condition is still somewhat obscure. The etchings from the Styliola limestone have furnished but a few barite replacements of shells which have assumed mature characters, but have afforded a goodly number of examples in elemental stages of growth. The character of the ornament serves to unite all of these as one species, and while there is still wanting a clear conception of the form of the suture at epheby, this is evidently closely approximated by that last exposed in the largest examples.

The following features will probably permit the ready identification of the species.

Shell widely and rather deeply umbilicated, the umbilication at the beginning of the fifth whorl being about three-fifths the diameter of the shell. This is, however, a feature subject to some variation, but the species is at once distinguished in this respect from its allies, *M. apprimatum*. and *M. Pattersoni*, though closely resembling herein *M. tardum*.

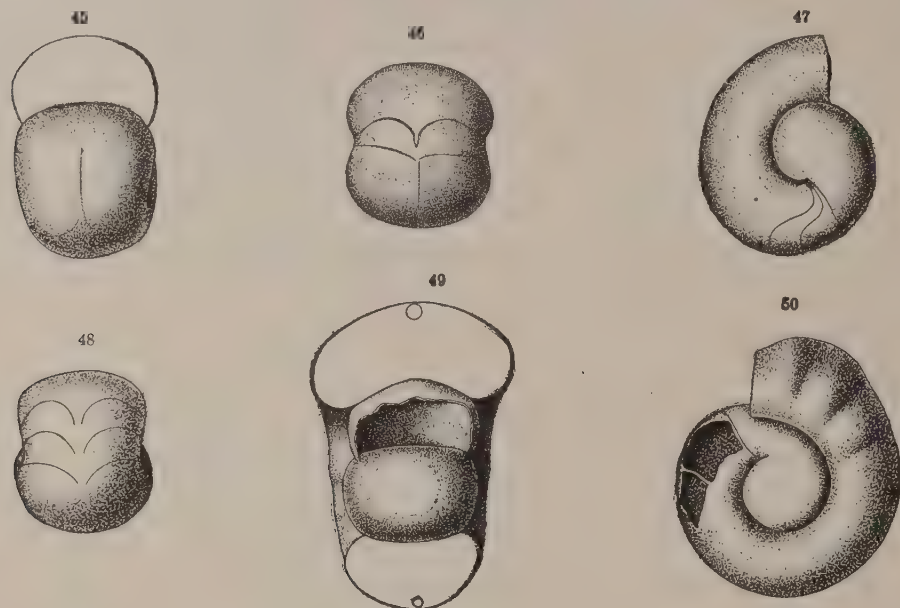
The later volutions have a broadly sagittate section, the venter being rounded and the sides gently convex; the umbilical slope is very abrupt.

The suture has a simple manticoceran form, the lateral saddles being comparatively large, inclined toward the umbilicus, and narrow or subacute at their extremities; the ventro–lateral lobes are long and acute; the ventral saddles are well developed and the umbilical lobe is a broad and simple curve.

The Immature Shell. *Protoconch.* This is frequently preserved either free or in connection with later parts of the shell. It has about the same size and very much the same form as that of *Mantic. Pattersoni*. Toward its distal end it is inflated, so that the sides of the protoconch protrude noticeably beyond the edge of the first whorl. Viewed from its distal surface it is transversely ellipsoidal; seen from the opposite side it is broadly clavate.

The Conch. At the first overlap contact of the protoconch with the conch the latter has considerably less diameter than the former and in section is shallow and very broad, the venter being depressed, but not flat. The relative increase of the conch in depth (dorso-ventrally) is extremely slow, as will be seen from an inspection of the accompanying figures, and not until the beginning of the fourth volution is there a decided tendency to alter the form of the cross-section to that presented in the more nearly mature shell.

Our material is insufficient to justify a definite statement as to gain or loss of umbilication or the stage at which any such change may have taken place. We content ourselves with the statement that the older shells present a

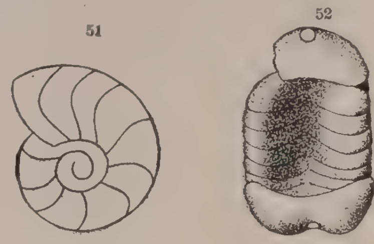


Figures 45–50. *Manticoceras fasciculatum*. Views of the protoconch and nepionic shell. x25. Fig. 45, protoconch from its proximal side, showing scar of siponal caecum; fig. 46, rear view showing first and second septum and mark of siphonal caecum; fig. 47, lateral showing protoconch, nepionic shell and first three septa; fig. 48, rear view showing three septa; fig. 49, fragment of nepionic and ananeanic shell, showing distal end of protoconch: fig. 50, side view, showing ananeanic corrugations.

relatively smaller umbilicus and hence indicate an increase of overlap of the whorls toward or at maturity.

Ornamentation. The opening of the neanic stage is marked by the abrupt appearance of simple varices, but there appear to be very few of these (not more than three or four) at equal intervals, as they begin to come in directly in pairs. In this form they may be traced for a full volution before there is any evidence of intercalary striae in the intervals. The grouping of the varices in this duplicate way is not lost even after the introduction of the finer accessory lines. Gradually the members of each pair become more or less merged into each other and the result is an elevated ridge grooved on top and separated from its neighbors by a tolerably deep furrow. This is the condition through the third and fourth whorls, but in later growth the striation becomes more diffuse. There is some similarity here to the mode of introduction and development of the varices, and their occurrence in *Mantic. contractum,* but we have elsewhere indicated the actual differences and the distinction in ultimate effects.

The Suture. The suture of the first septum makes a nearly transverse course across the conch, the broad outward curve forming only a faint saddle, but a moderately deep and sharp ventral lobe is produced. The edges of the septum do not come together to enclose this lobe, that is, the sipho lay against the wall of the conch at its passage into the protoconch, and its course over the inner wall of the latter is seen on many specimens as a long scar of the caecal extremity of that organ.



Figures 51, 52. *Manticoceras fasciculatum.* Fig. 51. Median section of first two whorls. x 12. Fig. 52. Dorsal surface of part of first whorl, showing dorsal lobe. x 25.

A similar trace of the sipho may often be seen on internal casts of the first two or three air chambers.

The second septum shows a very decided development of the lateral saddles and a sharper development of the ventral lobe; at this stage of growth the course of the septum on the dorsal side of the whorl is almost precisely that on the ventral, except that the dorsal lobe is slightly less developed. In the course of the second and third whorls there is a constant increase in the size and prominence of the ventral lobe, which then occupies fully one-half of the broad ventral surface of the whorl, the lateral saddle becomes more prominent and occupies the shoulder of the volution and the lateral lobe of about the same size occupies the lateral exposure of the whorl, recurving at the umbilicus to form a low saddle. There is no modification of the large ventral lobe until the fourth whorl, where its lateral slopes become divided and the ventro-lateral lobes are formed, with a narrow, intervening ventral saddle.

On the dorsal side of the whorl the development of the suture continues nearly *pari passu* with that on the exposed surface, up to the opening of the third whorl. Thereafter follows a rapid increase in the prominence of the lateral saddles which is not equaled by that of the umbilical saddles. In the course of the third volution the dorsal saddle is divided forming two small saddles and an intervening lobe, and the median dorsal lobe becomes very much narrowed. The suture up to this point has attained all the divisions which it presents in fuller development at later stages.

Figure 53. *Manticoceras fasciculatum.* Ventral view of the first half of third whorl, showing the corrugations and the course of the septa. x 25.

While we have referred this species to MANTICOCERAS it is not done without reservation. The mature form of the shell is in harmony with

typical examples of that genus both in whorl section and in the course of the suture, but in the development of both of these features there is certainly a wide difference between this species and *Mantic. intumescens.* Thus the great breadth of whorl, which in *Mantic. fasciculatum* continues through fully four volutions, is hardly more than suggested in the early stages of *Mantic. intumescens*, and the exceedingly large acuminate ventral lobe of *Mantic. fasciculatum* which is unmodified up to the fourth volution is remarkable, as this primitive lobe is soon modified in typical MANTICOCERAS and at no time has such a degree of prominence. Whatever the significance of these differences may prove to be, the species must, for the present, be left with this genus.

Occurrence. Manticoceras fasciculatum has been found only in the Styliola limestone, on Canandaigua lake and in the village of Middlesex, Yates county.

MANTICOCERAS NODIFER, Clarke.

Plate VI, Figs. 24–26.

1885 *Goniatites nodifer*, Clarke, Bull. U. S. Geol. Surv. No. 16, p. 21.

This species was based upon a few small shells from the Styliola limestone which were described as follows: "Shell umbilicate, body-whorl expanding rapidly outward, its width at the stoma being two and one-half times that at the beginning of the volution, compressed laterally, sloping gradually to the dorsum [venter] which is rounded; widest on the inner margin where it falls away abruptly to the inner whorls. The umbilicus shows five whorls which overlap one another in such a way as to leave each preceding one exposed for about one-fifth of its width. Diameter of the normal full grown shell 14 mm., of which the umbilicus covers five mm. *Suture:* Dorsal [ventral] lobe short, lanceolate; dorsal [ventral] saddles small, rounded and sloping slightly toward the umbilicus; outer lateral lobes somewhat narrower than the dorsal [ventral] saddles but of the same length; lateral saddles broad, rounded, twice as long as the dorsal [ventral] saddles, and distinctly sloping toward the umbilicus. Inner lateral lobe short, rounded and the ventral [dorsal] saddle small and indistinct. The inner whorls are edged with strong nodes, which may be the protruding ends of ridges passing across the whorls. These number from 12 to 16 for each whorl, but become fainter on the younger [later] whorls and are hardly distinguishable on the last volution. No other marks of ornamentation are visible."

The distinguishing features of this species are its narrow and deep umbilication and nodose inner whorls. Among the material acquired since

the original description none bears all of the characters here outlined. Upon a re-examination of the types of this species now in the National Museum, I am convinced that the strong nodation of the inner whorls is not a fasciculation of the concentric striæ, though undoubtedly having originated therefrom. Thus we may conceive this early nodose condition in *M. nodifer* to represent an advance over the corresponding growth stages in *M. fasciculatum*. We have placed the species under the genus MANTICOCERAS because of the form of the shell, notwithstanding the fact that the suture has attained only a gephyroceran stage and is immature or uncompleted with reference to MANTICOCERAS.

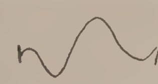


Figure 54. *Manticoceras nodifer*. Adult suture.

From the Styliola limestone, Genundewa, Canandaigua lake.

MANTICOCERAS PATTERSONI, var. STYLIOPHILUM, var. nov.

Plate VI, Fig. 30.

This is the characteristic variation of the specific type most abundantly developed in the Styliola limestone. It is emphasized by its accelerated phylogerontic final whorl and rapid increase of umbilication on the last volution, an additional gerontic character. The size attained by this form is small. Most of the specimens are from the outcrops of Styliola limestone on Canandaigua lake, and a single representative of the same accelerated type has been found in the Naples fauna.

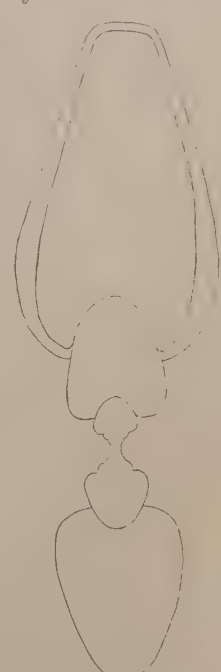


Figure 55. *Manticoceras Pattersoni* var. *styliophilum*. Section showing the contour of the whorls. Somewhat enlarged.

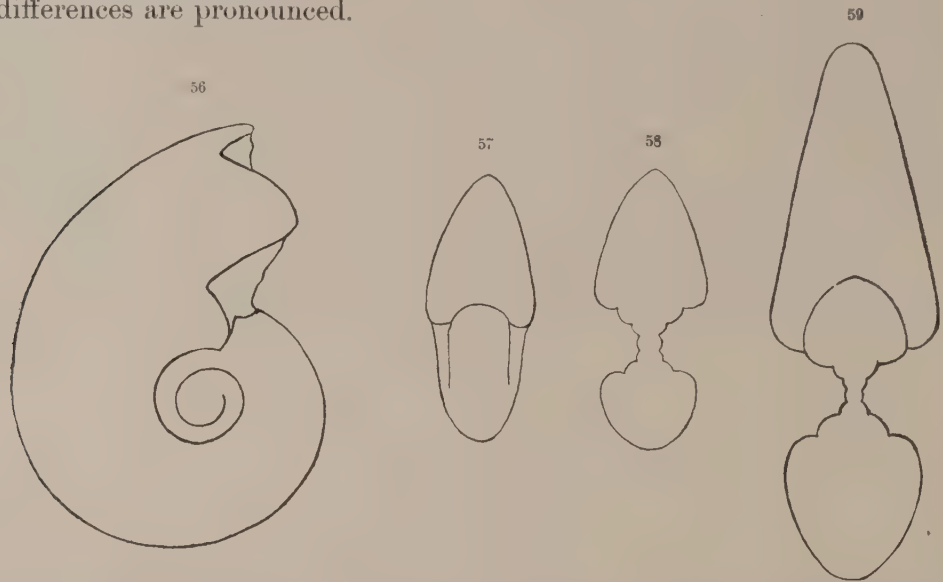
MANTICOCERAS SORORIUM, sp. nov.

Plate IV, Figs. 1–5.

Of immature examples of this shell we have a very considerable number from the Naples strata in the vicinity of Angola, Erie county, though still lacking a satisfactory knowledge of the fully mature shell. The numerous specimens examined do not exceed four volutions nor an extreme diameter of 25 mm., therefore we are not entitled to assume that fully mature shells have yet been met with.

At the maximum size referred to, the general appearance of this shell is remarkably like that of *Mantic. Pattersoni* in its normal adult state or rather approximates the var. *styliophilum* in which the final conch-section is more narrowed and sagittate.

In the form and size of protoconch, degree of umbilication and character of septation we shall find no distinction from *Mantic. Pattersoni* and its paraphase *Mantic. rhynchostoma;* but in respect to whorl section and ornament the differences are pronounced.



Figures 56–59. *Manticoceras sororium.* Fig. 56. Side view of young shell, showing suture ; Figs. 57–59. Outlines showing the rapid change in whorl section. x3.

Only in early volutions does the whorl section approach that of *Mantic. rhynchostoma.* The rapidity with which the shell narrows during the third and fourth volutions, and passes beyond the ultimate section of adult *Mantic. Pattersoni*, is well shown in the accompanying outlines. In the final observed whorls the shell approaches, without attaining, carination.

The ornamental lines consist at first of strong and simple varices ; these maintain their simplicity for a considerable period and are remarkably strong during the course of the third volution and early part of the fourth volution, where in allied forms the striæ have become subdued. They are especially noteworthy for their sharp curvature, the hyponomic curve being a narrow and deep festoon, accompanied by strong forward curves on the hyponomic ridges and broad backward curves on the lateral slopes. Although these varical lines are obsolescent on the fourth whorl, they at no time assume the character of pilæ.

The lateral compression of the final volution together with the character of the ventral curvature of the varices, brings into prominence the venter as a narrow peripheral band.

Manticoceras sororium has been found only in the vicinity of Angola, on the lake Erie shore and along Big Sister and Farnham creeks, Erie county.

Manticoceras accelerans, sp. nov.

Plate VI, Fig. 10.

A tachygenic phase of *Mantic. intumescens* is presented by this small shell which is, perhaps, in its normal condition, somewhat less umbilicated than that species. At a growth stage where the diameter of the shell is 22 mm. the suture has attained the curvature characteristic of the adult *intumescens*, but the septa are very closely crowded and are nearly parallel, so that the interval between them is of about the same width throughout their extent, a feature strikingly different from the condition in *Mantic. Pattersoni* where the interval between successive saddles is great and between successive lobes small. In the last half-volution there are nineteen of these closely appressed septa. This is a rare form of which we have seen but two specimens, both from the soft Portage shales at Naples, N. Y.

Figure 60. *Manticoceras accelerans.* The sutures in natural size and position.

Manticoceras oxy, sp. nov.

Plate II, Figs. 5, 6; Plate III, Figs. 1–3.

This name is applied to a shell which may be regarded as in all respects, an ultimate expression of *Mantic. Pattersoni.* It is of large, indeed of gigantic size, its final whorls are sharply carinated and its septal sutures show extreme development of all curves. Its gerontic expression in these particulars is fortified by its late appearance in the fauna. Specimens are not known in the lower beds of the Portage group and the species first appears not far below the horizon of the Portage sandstones, sometimes in soft sandy shales, sometimes in the flagstones, and again above the horizon of those sandstones in what have been termed the Wiscoy beds of the Portage group. Such a shell as this was included by the Sandbergers and F. Roemer within the limits of *Mantic. intumescens.**

We have represented on our Plate II a nearly entire individual of this species, though of small size in comparison with other specimens found. This

*Sandbergers, *op. cit.* pl. vii, fig. 1 a, b; Roemer, Lethæa palæozoica, pl. 35, fig. 10. Roemer's figure has been reproduced in such works as Koken's Die Vorwelt and Steinmann and Doederlein's Elemente der Paleontologie, as exemplifying this species, though, as we have already explained, Beyrich's original was a shell without carination.

In this connexion attention may be directed to the interesting shell identified by d'Archiac and de Verneuil with the *Gon. Hœninghausi*, v. Buch. We have elsewhere observed that v. Buch's species is synonymous with *Mantic. intumescens.* That figured by the French authors (Descr. Foss. Rhen. Prov., pl. xxv, figs. 7 a. b.) is a quite distinct species. It is a large, sharply carinate shell, with an accessory saddle which, Holzapfel observes, must exclude it from the genus Manticoceras (Das Obere Mitteldevon im Rhein. Gebirge, 1895, p. 117). Notwithstanding the fact that it is an upper middle Devonian shell, both its form and its suture evince its great acceleration. Morphologically it is an important link between Manticoceras and Beloceras (Holzapfel), but its time relations to the former genus indicate that we have still much to learn of the earlier history of Manticoceras.

shows the acuteness of the venter and the quite direct lateral slopes of the whorl to its periphery. In some specimens from the more arenaceous beds the periphery appears to be erected into a knife-like edge or crest, two or three millimeters in height.

The angulation of the venter is the natural extreme of the process of narrowing through which the *Intumescens* whorl passes from larval stages onward and which, as we have already observed, is carried further forward in the var. *styliophilum* than ever in the normal. If ever approximated in the normal it could be only in non-reversional, extreme gerontic stages. The great size of all such shells is, of itself, corroborative evidence of such a phylogerontic condition, as is also the rapid repetition of the septa. Again, the extremely elongate-lanceolate ventro-lateral and lateral lobes, are ultimates along lines already established in the growth of the normal.

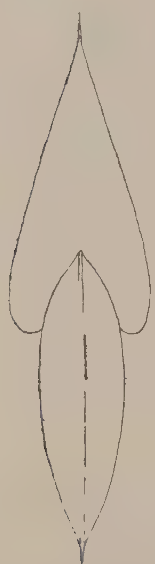


Figure 61. *Manticoceras oxy.* Restored outlines of final growth stage; ⅓ nat. size.

No specimens thus far observed show the character of the early ornamentation; but a fragment of a large dead shell with Orbiculoideas attached to the inner surface of the body chamber, shows broad undulations, like pilæ, concentric with the growth lines (see Plate III, fig. 1). This specimen also clearly shows the character of the aperture of the shell.

The entire specimen here figured has a diameter of 200 mm.; this is from the soft shales, 150 feet below the Portage sandstone, at the lower Portage Falls on the Genesee river, the lowest horizon at which the species has been found. A second nearly entire specimen with a diameter of 320 mm. is from the Portage sandstones, in Stony Brook Glen, near Dansville. Fragments of very large examples which must have measured from 460 mm. to 600 mm. (18 in. to 2 feet) in diameter have been found at Castile, just above the Portage sandstones, and in the flagstones below this horizon in the village of Naples.

MANTICOCERAS VAGANS, sp. nov

Plate VI, Figs. 11, 12.

The high degree of acceleration indicated in *Mantic. oxy* by the sharp carination of the final whorl, is carried to still earlier growth stages in a species from an altogether unusual association. The fragment represented on Plate VI, figures 11, 12 is all that is now known, but this is sufficiently distinctive in

its characters to show that we have here to do with an especially interesting form. The specimen is of rather small size, the final whorl shown being relatively broad and sloping in convex curves to a sharp, though not keeled ventral edge. This whorl is septiferous and is evidently one of the inner whorls of a somewhat larger shell, and we have had no other instance of this carination, potentially gerontic in *Mantic. Pattersoni*, parephebic in *Mantic. oxy*, doubtless metephebic in *Mantic.* (?) *Hoeninghausi* and *Mantic. carinatum*, here distinctly developed at the beginning of epheby. The sutures are normal but crowded, as shown in the accompanying figure, and the surface of the whorl shows concentric rugæ.

Figure 62. *Manticoceras vagans* sections of early ephebic whorls; nat. size.

This specimen was found in a loose block of sandstone among the Portage outcrops in the town of Naples, and is associated with numerous examples of *Productella speciosa*, *Leptostrophia mucronata* and *Ambocœlia umbonata*. It has evidently been derived from a concealed layer in or even above the upper sandstones, the species themselves indicating an incursive association from the eastward fauna.

RECAPITULATION.

THE PARAPHASES OF MANTICOCERAS.

We have here endeavored to emphasize the significance in the ontogeny of this genus, of what have been usually regarded as differentials of minor value. The ornamentation, its mode of introduction and modifications in growth can now be properly estimated in determining the genetic position of its species. In this generic group it is not to be considered of inferior significance to the phases of septation itself. The conch was less quickly responsive to organic influences and hence the whorl section maintains a uniformity in its changes which makes it one of the most dependable characters of the genus; notwithstanding, its phases serve to indicate very definite values in growth and decline. Umbilication is a feature whose significance is often less easy to gage, but whose value we have pretty clearly defined in our standard of comparison, *Mantic. Pattersoni*. As to the embryonic (protoconch) and nepionic stages, they prove to be invariable in all species here studied; only with the close of the nepionic phase do external differentials clearly manifest themselves. Such diverse expressions of the genus can not be properly estimated without consideration of the local conditions with which they are involved.

Manticoceras Pattersoni itself prevails and abounds in the more easterly extension of the Intumescens-fauna, in the Ontario and Livingston county region; but west from the Genesee river it becomes constantly more infrequent and in the vicinity of lake Erie its place in the fauna seems to be taken by *Mantic. rhynchostoma*, the remarkable species which in its mature condition or in its average adult size is wholly indistinguishable from *Mantic. Pattersoni*, while these ephebic characters are attained in passing through growth stages distinctly distinguishable from those of that species.

In this westward extension of the fauna occurs also the accelerated species *Mantic. sororium*, whose mode of acceleration is similar to, but more extreme than that of *M. Pattersoni*, var. *styliophilum* of the prenuncial fauna of the eastward region. Rapid acceleration is especially noteworthy in the species from the higher strata of the formation, especially in the carinate shells *Mantic. vagans* and *Mantic. oxy;* even, indeed, in *Mantic. Pattersoni* itself in its latest manifestations.

Manticoceras Pattersoni.

In assuming *Mantic. Pattersoni* as the yard-stick with which to measure the various manifestations of the genus here presented, we do this, as previously explained, because it is the most characteristic MANTICOCERAS of the fauna, the most abundant, and the most typical expression of this generic combination. Other species are, hence, most intelligibly expressed in terms of this. It is not regarded as an elementary, so much as a standard expression; for it exhibits acceleration in several respects. With reference to the simplest expression of the genus deducible from the data, though this expression be not represented by any known species, it is clear that *Mantic. Pattersoni* is considerably accelerated in the mode of introduction of the ornament, and distinctly if slightly tachygenic in conch-section, umbilication and septation.

Manticoceras apprimatum.

The whorl section indicates slight acceleration. The umbilication, which is very close, we interpret as indicative of a moderately arrested development. There is no phase of *Mantic. Pattersoni* where the umbilication is so slight as here, but this retention of centripety is, in the standard, a condition prevailing in early ephebic stages. In the matter of ornamentation, the simple varices with undivided interspaces continuing through three full volutions, show that here is a more primitive expression than in the standard, exhibiting a prolongation of what was there a brief growth period.

Manticoceras tardum.

The breadth of the whorl section indicates relative immaturity, while the long continued duration of the simple varices shows that the nepionic conditions in *Mantic. Pattersoni* were here greatly protracted. The wide umbilication indicates, to us, an uninterrupted continuation of the primary umbilication manifested directly after the embryonic stage, rather than the increase of umbilication which, in *Mantic. Pattersoni*, appears with the close of epheby and during gerontic growth. This interpretation is in accord with the elementary expression of the ornament, the whorl section and the septation.

Manticoceras simulator.

The expression of the standard species is here followed quite closely save in the immature character of the septation, the obtuseness of the umbilical lobe in all ephebic stages evincing a decided lagging of development.

Manticoceras rhynchostoma.

To restate our interpretation of this shell in its relation to *Mantic. Pattersoni:* Almost fully like results at maturity have been attained by both through very distinct phases of growth; while this growth might, in direction, be represented by parallel lines, in rate of development it must be represented by lines of unequal length and with deflected termini. The species is found in a part of the Intumescens province where *Mantic. Pattersoni* is not known to occur.

Manticoceras contractum.

The whorl section is nearly that of the standard, if somewhat broader and less progressed. The narrow umbilication we interpret, as in *Mantic. apprimatum*, to be an extension of the centripetal tendency which sets in at the sudden termination of the ananepionic maximum of umbilication. The ornament composed of fascicles of low varices suggests acceleration, as in *Mantic. fasciculatum*.

Manticoceras fasciculatum.

As in *Mantic. tardum*, the breadth of whorl section indicates immature attainment, though in fully mature conditions a palpable narrowing obtains. The wide umbilication we regard as in the preceding species, indicative of a prolonged ananepionic condition, while the ornamentation shows rapid acceleration in the brief existence of simple varices, their immediate duplication

and fasciculation, their outcome being a totally distinct expression in the exterior aspect of the shell. Septation is nepionic with reference to the standard.

Manticoceras nodifer.

So far as this species is understood, it indicates rapid acceleration in the character of its ornament, the nodes on the early whorls being an extremely advanced outcome of the regular concentric striation. In other respects, umbilication, whorl section and septation, the species is much more elementary in its expression.

Manticoceras Pattersoni, var. styliophilum.

We find here acceleration well marked in the narrow, depressed convex whorl section, and some slight degree of this quality in the increased umbilication, but in other respects this shell does not depart from the standard form.

Manticoceras sororium.

Tachygenic in its early acquisition of a narrow sagittate whorl section. Like *Mantic. rhynchostoma* it is restricted to the western part of the Intumescens province where *Mantic. Pattersoni* is not yet known to occur.

Manticoceras accelerans.

Distinct evidence of acceleration in a stage at, or approaching, epheby is shown in the close crowding of the septa. In other respects present evidence is not conclusive.

Manticoceras oxy.

The extreme lateral compression and carination of the whorl indicates great acceleration in this character, a fact distinctly fortified by the development of low pilae on the final whorl, the ultimate condition of the sutures, and the great size of the shell. This species affords the most pronounced example of acceleration.

Manticoceras vagans.

This species conforms to the standard, so far as known, except in the extreme acceleration of the whorl section which is acute and carinate in early ephebic, if not, indeed, at late neanic stages.

The following diagram is designed to express the variations of these various paraphases of MANTICOCERAS, as expressed above. *Mantic. Pattersoni*, as the standard of reference, is represented by a straight horizontal line.

Variations from this standard in any of the structural features specified is indicated by curved lines, the upward curve signifying acceleration, the downward curve, retardation; the degree of curvature also, expressing the intensity of these qualifications. Broken lines represent imperfect knowledge and parallel lines equality of development.

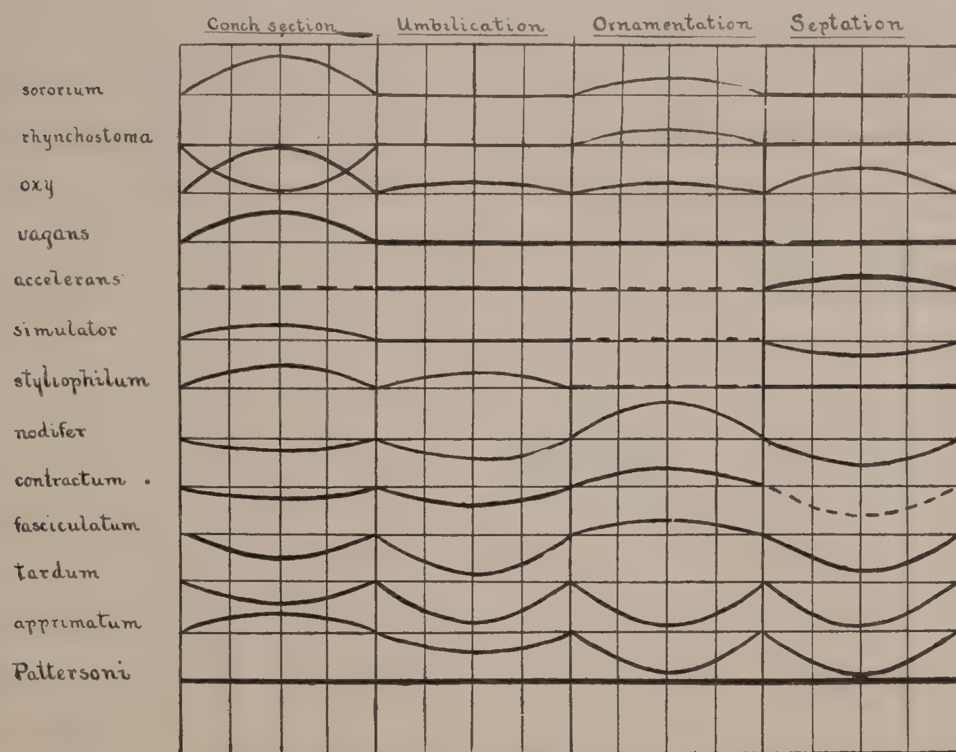


Figure 63

In the diagram below is shown the vertical range of the species of MANTICOCERAS in this zone, the basal formation being at the left of the figure.

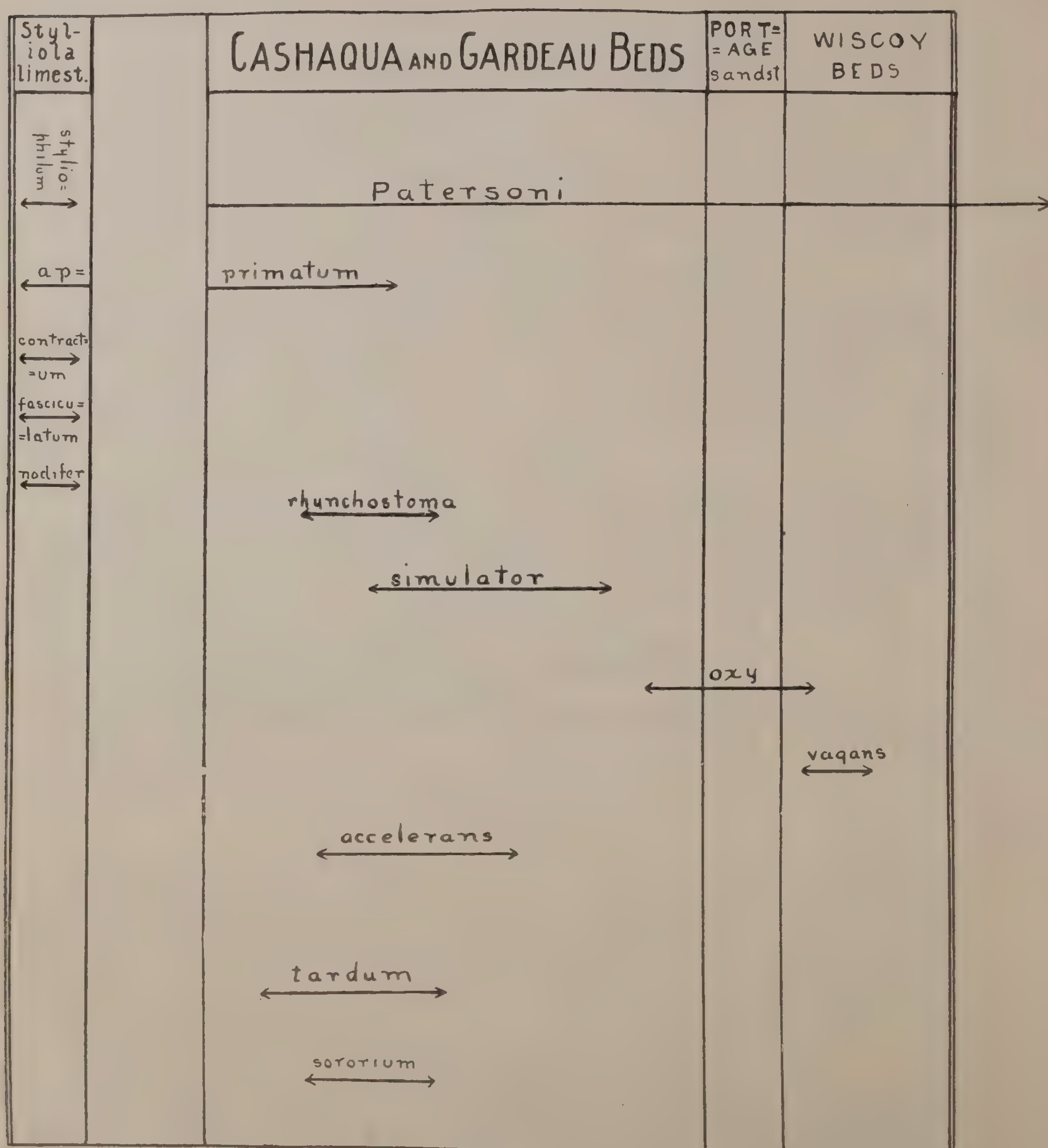


Figure 64

Genus Gephyroceras, Hyatt.

In discussing the character of the genus Manticoceras, it has been remarked that there is no real justification for the use of the term Gephyroceras, as its specified type is synonymous with the typical example of that genus. It is evident, however, that the author's intention was to embrace within this term species like *Gon. calculiformis*, Beyr., one of the examples enumerated and which is cited by v. Zittel, in illustration of that genus. Gephyroceras seems to us, to express a simple type and a point of departure for the development of more complicated generic forms, and we apply the term here, perhaps with some lack of precision, to species of this character which do not fit conveniently into other generic groups and at least one of which gives a starting point for a series terminating in the highly complicated suture of Beloceras. Curiously, the items in this series are contemporaneous. The relation of Manticoceras to these forms, is that of a well established structure derived from the same goniatitine stock, but progressed beyond the gephyroceran stage, for *Mantic. Pattersoni* shows clear enough evidence of passing certain features of the gephyroceran condition at a pre-ephebic stage, though at no time in its ontogeny can it properly be called gephyroceran, that is to say, has enough of these features evident at any single stage of its growth. Thus Manticoceras stands somewhat apart as a firmly established off-shoot from this stock, and consequently the other members of the Gephyroceras — Beloceras series are separated therefrom by a regularly increasing structural interval.

Gephyroceras perlatum, Hall (sp.)

Goniatites complanatus, var. *perlatus*, Hall. Descr. New Species Goniatitidae, p. 1, 1874; Twenty-seventh Ann. Rept. N. Y. State Mus. Nat. Hist. p. 132, 1875; Illustr. Devon. Fossils; Cephalopoda, pl. lxx, fig. 12, 1876; Palaeontology of New York, vol. v, pt. 2, p. 458, pl. lxx, fig. 12, 1879.

An inspection of the figure above cited shows the broadly recurved hyponomic lines indicating a low, convex and obscurely defined keel. The original specimen possesses the form and degree of umbilication characterizing the Gephyroceras — Beloceras series, but there is little that can be made out of its suture, only traces of a small umbilical lobe and a larger saddle being retained. The size of the shell is greater than in any of the allied species of this fauna. A second specimen in the collections of the State Museum is of about the same size as the original and gives a pretty clear conception of the mature suture. This shows a broad ventral saddle, prominent ventro-

lateral lobe, which is narrow and acute, a broad, rather low lateral saddle followed below by a moderately shallow and broad, rounded umbilical lobe and an acute saddle at the contact line. The form of this suture, if it has not been distorted by pressure is unlike that of other species of the genus here described, without varying from the gephyroceran type.

The original example is from Homer, Cortland county, the other from the vicinity of Ithaca. Both of these localities are in a region where the typical Intumescens-fauna is complicated with the brachiopod faunas characterizing the Ithaca series of central New York.

GEPHYROCERAS ? (PROBELOCERAS ?) GENUNDEWA, sp. nov.

Plate VIII, Figs. 1–3.

This is a small form, abundant in the Styliola limestone, and while it is described as a distinct species, it actually represents an immature phase of *Probeloceras Lutheri.* This apparently irrational interpretation is justified by the evidence that this form is a constant mature condition. The normal adult condition of *Probel. Lutheri* is not known to occur in this prenuncial fauna.

Gephyroceras Genundewa is, consequently, a small shell with a simple gephyroceran suture, its form discoidal, umbilicate and ventrally grooved as in *Probel. Lutheri* at a corresponding size. Its diameter seldom exceeds 8 mm. in any specimens which have shown septa. The suture of the last whorl is characterized by the large lateral saddle and broad, undivided umbilical lobe. This is such a shell (if smaller at maturity) as the *Gon. forcipifer*, Sandberger,* one of the species embraced by HYATT among those typical of the genus. While we admit its similarity to, and agreement with an immature phase of *Probel. Lutheri*, it is proper to distinguish it by a distinct specific and even generic name, for it is through such a distinct phase that the shell whose mature condition and history we characterize by the name *Probel. Lutheri*, passes in earlier growth. Should further investigation show the presence of *Probel. Lutheri* in the prenuncial fauna, this form must then be looked upon solely as one of its phases. *Gephyroceras Genundewa* would undoubtedly have become that species, had its growth not reached its final stage thus early.

The species has been not infrequently observed in the form of pyrite, barite and sphalerite replacements in the Styliola limestone at Genundewa on Canandaigua lake, at Middlesex and elsewhere.

* See SANDBERGER, Verstein. d. Rhein. Schicht. Syst. in Nassau, pl. VI. fig. 8.

GEPHYROCERAS HOLZAPFELI, sp. nov.

Plate VII, Fig. 17.

This species has the general expression of *Probeloceras Lutheri* in its compressed, discoidal whorls and flattened, grooved periphery. It is, however, somewhat more widely umbilicated and the form of the suture is one degree more simple, sufficient to exclude the species from an accurate generic association with PROBELOCERAS and showing again the close phyletic connection of the forms here termed GEPHYROCERAS, with the BELOCERAS series. At a stage of growth in which the suture of *Probel. Lutheri* is fully matured, that of *Gephyr. Holzapfeli* has obtuse lateral saddles and sublateral lobes, presenting in this respect, which is the mature condition of the species, a reproduction of an immature condition in *Probel. Lutheri*. The sharpening of these lobes and saddles is not attained by the species in any stage of growth, hence upon this difference, we place it with GEPHYROCERAS.

Figure 65. *Gephyroceras Holzapfeli*. The adult suture.

But a single example of this form has been observed, a pyritized shell covering slightly more than five volutions and showing septa throughout its extent. Its greatest diameter is 7 mm., a size about the same as that of *Prob. Lutheri* at the same stage of growth. The specimen was obtained by Dr. D. F. LINCOLN on Eighteen-mile Creek, Erie county, near the crossing of the Lake Shore railroad, and is believed to be from the lower Portage shales at this place. The similarity of the species to *Gon. forcipifer*, Sandberger, is striking, but there is a difference in the greater umbilication of the New York shell, in the sharper curvature of the umbilical lobe and slight development of the umbilical saddle.

GEPHYROCERAS CATAPHRACTUM, sp. nov.

Plate VI, Figs. 3–9.

Small specimens only are known of this species, the largest not exceeding 10 mm. in diameter. The form presents a number of interesting characters and serves, among other things, to again exemplify the rather loose construction that we feel compelled to place upon the genus GEPHYROCERAS.

This species has been found only in a calcareous concretion near Java village, in which it is exceedingly abundant, but the greater part of the specimens are preserved in calcite, making their extraction from the matrix a matter of extreme difficulty. Fortunately a small quantity of barium sulphate exists in the rock and has furnished some nice replacements, though they are exceedingly tenuous and delicate.

The Shell is deeply umbilicated, with smooth and broad whorls; the latter even in the most advanced adult conditions presented by the specimens, strongly suggesting by their dimensions, pre-ephebic conditions. The form of the whorl section through four volutions is shown in the accompanying vertical section through the protoconch. The specimen from which this figure has been made is practically ephebic, so far as we now understand the species.

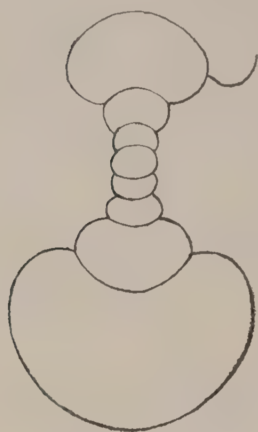


Figure 66. *Gephyroceras cataphractum.* **Enlarged section through the protoconch.**

Ornamentation. A fine concentric ornamentation is faintly visible over the earlier whorls but the later whorls are apparently smooth. The wrinkle-layer is frequently shown and bears exceedingly fine inosculating striæ traversing the whorls transversely. A feature of marked distinction in this species is the presence of collarets or labial ridges at irregular intervals in the later whorls. It is the only species of this zone in which such periodical thickenings of the shell have been observed, though they are of frequent appearance among the Rhenish goniatites. These collarets are sometimes slight and manifest themselves principally in the irregular growth and degree of overlap in the whorls.

Protoconch and early shell stages. The protoconch has not been isolated. It is, however, evidently of considerable size, distinctly protuberant beyond the first whorl. It tapers rapidly from its neck, or the commencement of the first whorl and at one-half revolution this whorl attains minimum width. The neanic condition is smooth for one-half volution, ends abruptly in an elevated, smooth varix, and is followed by striated nepionic growth. In all of these respects the shell is wholly and notably similar to *Manticoceras Pattersoni*.

Septation. The adult suture, that at four and one-half volutions, as shown in the adjacent figure, and those also, of earlier stages, are marked by the large and prominent lateral saddle, situated high up on the ventral shoulder. This is subacute at three volutions, but becomes blended in later growth. During the third volution the ventral lobe remains very broad and undivided; in the early part of the fourth volution, it becomes divided into short, acute ventro-lateral lobes and low ventral saddles. The umbilical lobe continues broad and blunt in all stages. There is a narrow, but sharp dorsal lobe with a low accessory lobe on the dorsal surface.

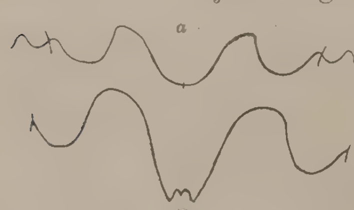


Figure 67. *Gephyroceras cataphractum.* *a.* The entire course of the suture at three volutions. *b.* The suture at four volutions.

The whole aspect of the most advanced condition of the suture, is that of relative immaturity, which endorses the general expression of the shell in other respects mentioned.

Locality. All specimens observed are from a ravine at Java village, Wyoming county, N. Y.

Among the more abundant goniatites of the Portage fauna are discoidal, widely umbilicated shells which have usually been permitted to pass with the designation "Goniatites complantus, Hall." We shall presently examine the value of this appellation. These shells, in their adult characters, afford a remarkable series of progressional phases from a simple type of suture like that of MANTICOCERAS to the most complicated form known in the Devonian faunas, BELOCERAS, represented typically by the German upper Devonian shell, *Gon. multilobatus*, Beyrich. Forms representing the precise phases about to be described have not, we believe, been elsewhere recorded. Indicatory as they are, not of the completed development of the typical BELOCERAS it is with some hesitation that any are referred to that genus. *Beloceras multilobatum* is a flat, umbilicated shell, like the species under consideration in all external characters and general aspect. Its suture, however, becomes highly serrated even at early growth stages, as shown by BRANCO,* and at maturity it consists of not less than fourteen lobes and saddles on each lateral slope, all being acutely angled except the minor auxiliary curves.† The SANDBERGERS' figures of the suture in this species show that there is an immature growth-stage in which the lobation of the septum corresponds with the adult condition in one of our species, *Gon. iynx*, where the lobes and saddles are but five in number, but the Naples species do not pass this degree of lobation, nor do they ever attain the large size of *Beloc. multilobatum.* Again, the Naples species, *Gon. iynx* with its five lobes, and *Gon. Lutheri*, with but two acute lobes and saddles, are so nearly alike in all respects except the form of the suture, as to be indistinguishable from each other when that feature is obscured. Their mature conditions when the shells are of equal size and of the same number of volutions, seem not to stand in immediate successive phyletic relation, for so far as our evidence goes there is no immature condition of *Gon. iynx* whose suture exactly reproduces the adult form of that of *Gon. Lutheri.* The small dorsal or sublateral auxiliary lobes of *Gon. iynx* are developed early and while the principal lobes and saddles are in an obtuse condition; thus in the rapid stride

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* Palaeontographica, xxvii, pls. vi, vii.

† See SANDBERGER, Verstein. d. Rhein. Syst. in Nassau, pl. iv, fig. 3f. and p. 56, fig. 7.

of the shell toward its adult condition the auxiliary lobes have been introduced before the sharpening of the main lobes and thus the *Lutheri* stage of the lobe has been hastened over and obscured. Nevertheless, there is clearly a place for it among the stages of *Gon. iynx* and the stage at which the *Lutheri* condition was skipped, could doubtless be made out with the study of somewhat more complete material. Of *Gon. Lutheri* we have a very complete knowledge of the developmental phases in all of its features and shall show that the ephebic suture is an outcome of a manticoceran condition preceded by a simpler anarcestian stage. There is probably no good reason for not incorporating *Gon. inyx* in the genus BELOCERAS, notwithstanding the fact that its condition with reference to *Bel. multilobatum* is immature; but the subdivision of the principal lobes and saddles in the former species is well established and the difference in the two is that of the extremes to which this division has been carried. An instructive instance of another intermediate condition more progressed than that of *Gon. iynx* is the *Gon. Kayseri*, Holzapfel, from the middle Devonian of Martenberg,* which bears in its mature stage eight mostly acute lobes and saddles, and in its degree of umbilication is a nearer approach to *Gon. iynx* than to *Gon. multilobatum.* For *Gon. Lutheri* we have proposed to introduce the generic term PROBELOCERAS, on account of the unimpaired simplicity of the mature suture.

(Family **Prolecanitidae,** Hyatt.)

PROBELOCERAS, gen. nov.

Discoidal, laterally compressed, umbilicated shells, with a narrow peripheral band, concave and with raised edges in immature stages, convex in the adult. Suture with a single large and acutely angled lateral saddle, and two acute lobes; ventral and sublateral lobes rounded. Early stages show a gradual derivation of the suture from a manticoceran outline by the sharpening of the principal saddle and sublateral lobe.

Type, *Goniatites Lutheri*, Clarke, 1885.

PROBELOCERAS LUTHERI, Clarke, 1885.†

Plate VII, Figs. 1–10.

General Form. *Adult.*

The full-grown shell is very widely umbilicated, disk-shaped, with narrow, deep whorls, subsagittate in section in all later growth-stages. The sectional outline gives the greatest convexity toward the umbilicus, and on the umbilical margin the slope is quite abrupt. The venter bears a sharply defined median surface extending like a tire about the periphery of the exposed

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*See Palaeontographica, viii, 6, p. 14, lxv, figs. 7–10.

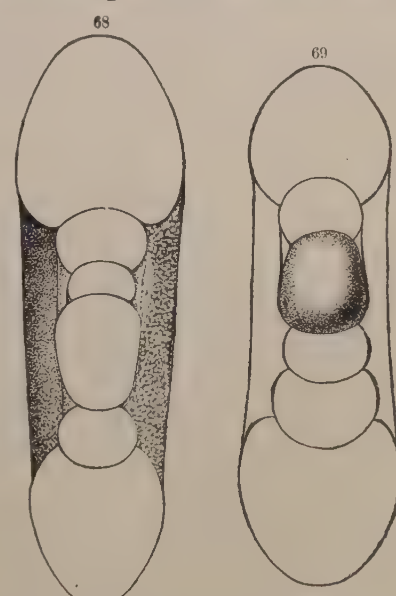
†See end of description for a full bibliography of the species.

whorl. In the final whorl this hyponomic tire is slightly elevated at the edges, each of which is sharp, and is broadly convex over the middle. Beneath the edges, on the lateral slopes of the whorl the surface is faintly depressed into two low revolving furrows which are greatly increased in depth by compression in fossilization. The form of the whorls varies very slowly in all later growth-stages, that is to say, the adult form is approximated at a very early stage of growth and afterward is subject to only unessential modifications. Very little variation in form is shown among mature individuals. In complete growth the number of volutions seems to not have exceeded eight, and in final stages the length of the whorl section is about three-eighths the entire diameter of the shell.

An average entire specimen measures about 60 mm. in diameter. The substance of the shell is very tenuous and the last whorl is rarely retained. There is nothing in the general aspect of the shell to distinguish it from *Gon. iynx.*

Development of Form. *The Protoconch.*

The primitive shell is of small size compared with that of the other species here described. This will be seen from a comparison of either side, back or front views with those of other species. Its form is remarkably similar to that in *Mantic. Pattersoni*, and shows, as already observed in that species, a greatest breadth at the posterior or distal extremity, which exceeds the diameter of the first whorl. The convexity decreases gradually, but, as in *Mantic. Pattersoni*, the first septum is passed before the minimum width is attained. Thus in the accompanying figures which give the protoconch, as viewed from the ventral side, it shows its characteristic swollen and pear-shaped contour.



Figures 68, 69. *Probeloceras Lutheri.* Vertical sections of young shells, showing the protoconch in position and presenting the proximal surface. x 25.

Here again, as in *Mantic. Pattersoni*, all observations indicate a slight asymmetry in the protoconch with reference to the first whorl. This is decidedly less than in *Mantic. Pattersoni*, and appears to be susceptible of slight variation in different individuals. The size of the protoconch is itself variable within the limits shown in our figures.

The Conch. With the commencement of the first volution, the whorl section is transversely semielliptical and about twice as wide as high. As observed already, the size of the whorl section diminishes from its inception,. as in *Mantic. Pattersoni*, but the decrease and subsequent increase are not so marked as in that species. Taking corresponding whorls of these two species, we shall find that at no time is the whorl section of the former relatively as broad as in the latter. In *Probel. Lutheri*, increase vertically goes on apace and the section at the end of the second volution is fully as long (dorso-ventrally), as the section at the end of the third volution in *Mantic. Pattersoni.* So far as the final form of the whorl section in *Mantic. Pattersoni* is reproduced in this species, it is found in the course of the third volution, but even here has superinduced upon it the ventral flattening which especially characterizes all subsequent growth stages and, in *Mantic. Pattersoni*, attains in eventual conditions somewhat the same degree of prominence as here in this early stage of *Probel. Lutheri.* We shall presently notice more at length, the variations accompanying the development of the ventral ridge in this species; its effect on the form of the whorl is most sharply marked in the fourth and fifth volutions, and thereafter it becomes a somewhat less defined feature of the conch.

Figures 70, 71. *Probeloceras Lutheri.* Front and lateral views of the protoconch and first whorl. x 25.

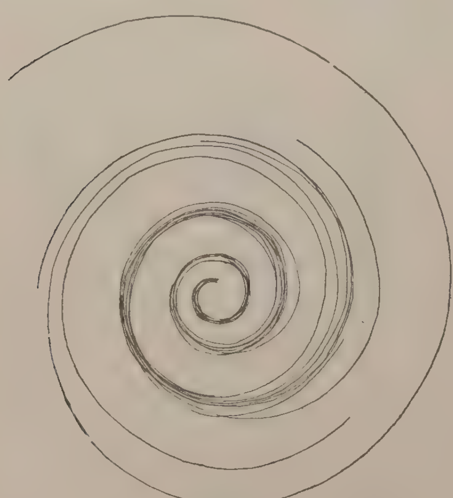


Figure 72. *Probeloceras Lutheri.* This is a composite figure consisting of seven outlines of the early volutions similarly oriented with reference to the protoconch and primary curvature. It shows the variations in degree of umbilication existing within the species.

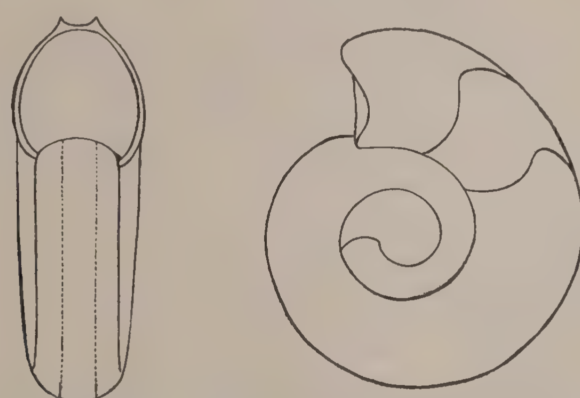
Umbilication. Notwithstanding the large umbilication of this species, we find here even more forcibly exemplified than in other species here discussed, the regular increase in the amount of overlap in successive whorls. This is continued to a definite growth-stage when it is followed by a rapid increase in umbilication to the final stages. In the figure 77, on page 96, which shows in section all the whorls in a normal adult, this variation in umbilication or degree of overlap is evident and may be expressed as follows, beginning with the overlap of the 1st by the 2nd whorl; .30, .33, .46, .41, .24. Thus there is an increase up

to and probably through the fourth volution and thence onward a rapid loss of overlap and increase of umbilication. In *Mantic. Pattersoni* we observed that this change from gain to loss of overlap occurred apparently in a late ephebic substage, but in this species this change is induced much earlier, before we should regard the ephebic condition as fully introduced.

Ornamentation. The barite replacements which have preserved the most delicate ornamentation in other forms, are here all smooth up to the close of the fourth volution or show only faint concentric lines. Calcite removals * show to better advantage such ornament as the species possesses.

Figures on Plate VII show that for nearly one and a half volutions the whorls are smooth, directly thereafter comes in a series of simple, low, elevated

73 74



Figures 73, 74. ***Probeloceras Lutheri.*** **Front and lateral views of a young shell of two volutions. Fig. 73 shows the prominence of the double ventral keel; fig. 74 shows the first and three of the later septa. x 25.**

striæ, the first of which seem not to extend to the umbilical margin, but those succeeding extend entirely across the exposed parts of the whorl. These become too faint to be seen shortly after the commencement of the fourth volution, showing at no place an intercalary series. Where the entire surface of the whorl is exposed it is seen that these lines extend with the faint curve indicated, to the venter, where they become abruptly elevated as they pass over the ventral flattening. In the specimen (barite) represented in figure 2 showing just two volutions, the strong lamellæ made by these lines at the ventral surface are shown, although the lines in their extent over the lateral slopes of the whorl are not retained. In viewing such a specimen from in

* A calcite shell embedded in an impure, argillaceous limestone such as composed the concretionary masses abounding in the Portage beds, upon being completely dissolved out by acids, leaves an exact intaglio which will show the finest detail of surface markings in case the specimen was in good condition before fossilization. The matrix, after its acid bath, is soft and clayey but upon being thoroughly washed and dried may be hardened by soaking in weak glue. After a second drying, the specimen will permit an impression in gutta-percha, if made quickly. Such impressions are referred to as "calcite removals." Many figures on our pages and plates are from these. The writer has found this simple process marvellously successful in the elaboration of structural details in many fossils.

front and behind, the lamellæ appear as a pair of crests bordering the lateral ridges of the ventral area, though they at once resolve themselves into the structure shown in such a view as figure 3, the lines bending retrally over the median ventral groove. It is probable that these lines become conspicuously elevated at a somewhat earlier stage than that represented in figure 2, but they are resorbed in consequence of overlap, and it will be observed that for a half-volution in this specimen these lamellæ have escaped resorption. In other specimens the ornamentation over the fifth volution consists of the primary striæ with intercalary striæ of somewhat irregular order and number,

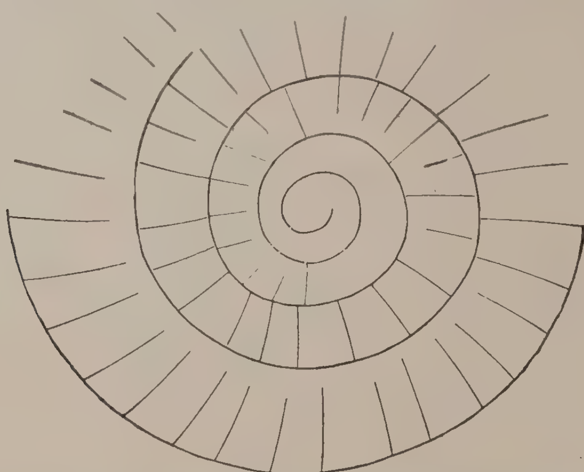


Figure 75. *Probeloceras Lutheri.* **The inner whorls, drawn from an impression of the exterior. This figure shows the protracted nepionic stage with its terminal varix and the mode of introduction of varices on the neanic whorls. x 25.**

the entire striation becoming more and more faint outward. Soon it disappears or is resolved into a uniform striation of the surface, which in the final condition may assume the aspect of an obscure undulation or pilation of the surface. The ventral lines remain sharp and strong throughout, though with gradual loss of intensity.

The hyponomic flattening. On account of the rapid change of form during the course of the first and second volutions, the whorl soon (two and one-half volutions) attains the outline characteristic of mature *Mantic. Pattersoni.* Even before this, and as early as the beginning of the second volution the ventral flattening is well defined, as shown in figure 73, where it is seen to be a groove bounded by elevated margins. Where the surface of the previous whorl has been overlapped and the lamellæ resorbed, the definition of the hypnomic flattening is obscure though apparent.

During the course of the fifth and sixth whorls the depth of the median groove and the elevation of its lateral ridges greatly increase, but thereafter

it becomes a less prominent feature, gradually losing its concavity and the sharpness of its lateral elevations, until, in final stages it is broadly convex medially with narrow depressions on the outer surface between the median convexity and the sides.

Septation. We have not been successful in isolating the protoconch of this species in such a condition as to elucidate the complete form of the first septum. The barite replacements seldom show the early septa and the same is true of the pyrite cast. Some of our figures show the direction of the first septum over the exposed surface of the whorl, but its course upon the venter has yet to be determined. During the course of the first volution only the very broad curve of the lateral lobe is exposed. At the end of this volution, at the seventh septum, the course of the suture is as follows: There is a broad ventral lobe dividing two low and obtuse ventro-lateral saddles; these are followed below by long, low, retral curves, forming the lateral lobes. The dorsal course of the suture is simple, the dorsal lobe being the only interruption of its simplicity. At one and two-thirds volutions and up to two and one-third volutions there is little alteration in the form of the suture, but directly thereafter the broad ventral lobe is divided by the introduction of a ventro-lateral saddle, which necessitates the appearance of a corresponding ventro-lateral lobe; these are never of equal size, the former being the smaller, and the slight difference between them at the outset becoming constantly greater throughout the remaining history of the species. With the completion of the third volution the lateral saddle has become greatly increased in length and breadth, the lateral lobe is considerably shortened and narrowed, and the ventro-lateral lobe subacute. This form is very closely reproduced in the anephebic conditions of *Mantic. Pattersoni* and in the mature state of *Mantic. simulator*, in which the suture is characterized by the great lateral saddle and the rounded lateral lobe. During the fourth volution the tendency is toward the narrowing and sharpening of all the lobes and saddles and their increase in actual size. Thus the fully mature suture as expressed in the fifth volution, has a large, acute lateral saddle, a ventro-lateral lobe of about the same shape and size, an acute but smaller lateral lobe, a subacute, narrow, ventro-lateral saddle and an acute, moderately long ventral lobe.

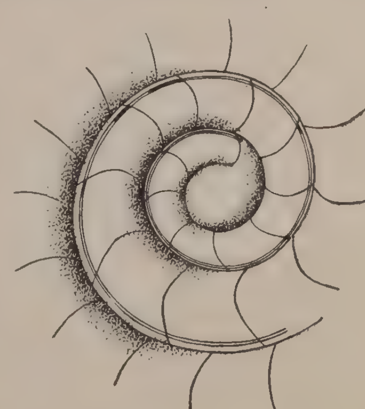


Figure 76. *Probeloceras Lutheri.* The inner whorls of an adult shell drawn by transmitted light; showing the septa and sipho. x 25.

In the course of the early volutions the septa are relatively more distant than in the later growth of the shell. This appears to be a regular increase in degree of septation. Thus there are seven or eight septa in the first volution, eleven in the second, fifteen or sixteen in the third and as many as forty or forty-five in the fifth.

Distinction of the Stages of Growth. It has already been remarked that the growth-stages, which are pretty clearly defined in the species *Mantic. Pattersoni* are here somewhat obscured on account of the absence of sharply marked surface sculpture. Nevertheless by close analysis of this feebly developed trait aided by the evidence afforded by variations in septation, umbilication and whorl section, it becomes possible to deduce some rational inferences regarding the division and duration of the growth periods.

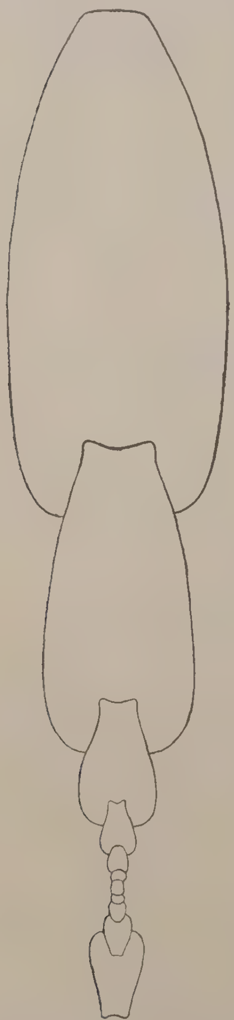


Figure 77. *Probeloceras Lutheri*. Vertical section from protoconch to adult whorl showing successive loss and gain of umbilication, the variation in the form of the whorl section and the modifications of the ventral sulcus. Enlarged.

The *nepionic* period in some other species is represented, as we have noticed, by a smooth shell, which in *Mantic. Pattersoni*, extends for about a half-volution. In *Probel. Lutheri* this shell is also smooth and the best of our preparations indicate that the smoothness of surface was continued for at least one entire volution. It is also evident that an ananepionic substage is defined by the retention of the embryonic convexity of the shell over the incipient part of this conch, a metanepionic substage by the abrupt decrease of diameter of the whorl section, and a paranepionic condition by the gradual return to a normal rate of whorl expansion. If the nepionic stage of growth was longer continued than in some other species, as suggested by the smoothness of the entire first whorl, its duration was an increase only in the paranepionic substage, for the embryonic, ananepionic and metanepionic conditions correspond throughout in the amount of shell formed, with the same stages in *Mantic. Pattersoni*. The termination of the smooth surface affords a whorl section which is notable as showing the first inclination to lateral flattening. So far as our evidence now extends, there is, in the septation of the shell, no innovation which comes in with the assumption of the surface ornament and lateral compression of the whorl. Throughout this period the septum has probably maintained its form without

essential modification, the suture showing a gradual increase in the strength of the primitive lateral saddles and this increase is continued through and beyond the period of the smooth conch, probably for one-half to three-fourths of a volution. The formation of the hyponomic sulcus was contemporaneous with the introduction of the other surface ornament.

The neanic stage. This is opened by the appearance of the simple, low, elevated surface lines and the commencement of the hyponomic sulcus. During its initiative stages the form of the whorl attains the outline characterizing that of the mature normal MANTICOCERAS, with the ventral flattening superinduced upon it. Such a form is that presented by a species like *Mantic. carinatus* Beyr. in which the *intumescens* suture is associated with a ventral keel, or like that afforded by late gerontic conditions of *Mantic. Pattersoni*, when the ventral ridge becomes best defined.

The *intumescens* characters have not, however, developed *pari passu* and are not presented simultaneously. That is to say, the neanic stage covers the entire period in which the *intumescens* traits are presented in respect to ornamentation, septation and whorl section, but at the precise time when any one of these is nearest its expression in the mature *Mantic. Pattersoni*, the others are not coincident. Thus the *Pattersoni* whorl section is here attained near the beginning of the third volution. This is one-half volution after the introduction of the simple ornament and nearly a half volution before the disappearance of the simple anarcestian suture, and the appearance of the ventral saddle and ventro-lateral lobe. The anephebic *intumescens* suture (that of *Mantic. simulator* with rounded lateral lobe), is well-defined only at the end of the third volution. The umbilication is a feature in which there is no agreement with *Mantic. Pattersoni*, except in the primary volution of the shell in both. It is a character which gives a pronounced individuality to the species from the nepionic stage upward, and though passing through a successive gain and loss, it is always of a different degree than that of *Mantic. Pattersoni*. The neanic stage is clearly the period of assumption of the *Pattersoni* characters, the *Pattersoni* growth-phase.

The ephebic stage. Beginning with the fourth volution, the whorl section becomes increasingly narrow and the venter flattened and deeply concave. The normal suture with sharp lobes and saddles is well-established in the course of the fourth volution, its later growth consisting of increase in size and length. Ornamentation has become modified by the introduction of fine intercalary striæ. At the end of the fourth volution, umbilication has

attained its minimum, the overlap of the fourth upon the third volution being now the greatest. We may be justified in regarding this volution, as the exemplification of the early ephebic stage and the period of establishment of mature traits. It is not possible to delimit the perdurance of such features without modification, but it may be observed that in a fully completed shell there are two or three more volutions. These whorls show two very excellent evidences of senility; (1) the increase in umbilication; (2) the close crowding of the septa. They are also characterized by gradual filling up of the depressed ventral groove and its loss of definition.

CORRELATION OF GROWTH STAGES OF PROBELOCERAS LUTHERI.

Stages.		Form.	Umbilication.	Ornamentation.	Septation.
Embryonic		P R	O T O C	O N C H	
			(Anarcestes	stage.)	
Nepionic	Ananepionic	Maximum relative size of conch section.	(a)	Smooth to $1\frac{1}{3}$ volutions.	
	Metanepionic	Loss of diameter.	Abrupt increase.		
	Paranepionic	Increase of diameter.	Decrease.		Anarcestian.
			(Gephyroceras-	Manticoceras stage.)	
Neanic	Ananeanic Metaneanic Paraneanic	Gradual lateral compression of whorl and attainment of normal intumescens form	Regular decrease of umbilication to end of 3d whorl.	Introduction of simple distant concentric striæ and ventral flattening. Ventral crests highest toward end of this stage.	Introduction of ventral saddle and ventral lobe at $2\frac{1}{3}$ volutions. *Mantic. simulator* suture at $3\frac{1}{4}$ volutions.
Ephebic	Anephebic Metephebic Parephebic	Rapid narrowing of whorl extending from the venter downward; widening of venter and shallowing of hyponomic groove.	Decrease in the 4th volution, gradual change and increase in later volutions.	Introduction of fine intermediary striæ and general loss of size in concentric striæ. Shallowing of hyponomic groove.	Angulation of lateral lobe early in 4th volution. Narrowing of angulation of all lobes and saddles in 4th and 5th volutions.
Gerontic	Anagerontic Metagerontic Paragerontic	Obscuration of ventral flattening and assumption of convexity.	Rapid increase in all stages.	Obscuration of hyponomic flattening and assumption of convexity.	Crowding of septa in all later stages.

Probeloceras Lutheri, Clarke, 1885.

1843 (?) *Clymenia ? complanata*, Hall. Geology of New York, Rept. Fourth Dist., p. 244, fig. 106, 5 (p. 243).

1861 (?) *Clymenia complanata*, Hall. Descr. New Species of Fossils, p. 35.

1861 (?) *Clymenia Erato*, Hall. Descr. New Species of Fossils, p. 36.

1862 (?) *Clymenia complanata*, Hall. Fifteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 63.

1862 (?) *Clymenia Erato*, Hall. Fifteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 64, pl. x, fig. 1.

1874 (?) *Goniatites complanatus*, Hall. Descr. New Species Goniatitidæ, p. 1.

1875 (?) *Goniatites complanatus*, Hall. Twenty-seventh Ann. Rept. N. Y. State Mus. Nat. Hist., p. 132.

1876 (?) *Clymenia Erato*, Hall. Illustrations of Devonian Fossils: Cephalopoda, pl. lxx, figs. 6, 7.

1876 *Goniatites* (*Clymenia*) *complanatus*, Hall. Illustrations of Devonian Fossils: Cephalopoda pl. lxx, possibly figs. 10, 11, nat. 8, 9.

1879 *Goniatites complanatus*, Hall. Palaeontology of New York, vol. v, pt. 2, p. 455, pl. lxx, possibly figs. 10, 11; not figs. 8, 9; probably not figs. 6, 7.

1885 *Goniatites Lutheri*, Clarke. Bull. No. 16, U. S. Geol. Surv., p. 50, pl. ii, fig. 8.

Not *Goniatites complanatus*, Hall. Palaeontology of New York, vol. v, pt. 2, Suppl. pl. cxxvii, fig. 2, 1888.

Historical. The shell described by Professor Hall in 1843 (*op. cit.*) as *Clymenia ? complanata* represents the exterior of a flattened specimen, showing a characteristic evolute form and a fine concentric surface striation. The septa, however, are totally concealed. In view of the fact that there are now known to be at least three well-defined species in the Portage shales which seem to have precisely the character of exterior ascribed to *Clymenia ? complanata*, it would be possible to determine the exact value of this species only by careful re-examination of the original example. Where this original now is, can not be ascertained. It is not in the collections of the New York State Museum, nor has it been found among the Portage material in the American Museum of Natural History in New York, through which the writer has, by the kindness of the curator, Mr. R. P. Whitfield, several times carefully searched. In the latter collection there are certain specimens, however, marked *C. ? complanata*, whose labels indicate that they were collected

during the progress of the survey of the Fourth District; some of these have the sutures of *Probel. Lutheri*, and the others show only the exterior. Subsequent identifications of this species afford little assistance as to its essential characters.

In the Fifteenth Ann. Rept. N. Y. State Cab. (1861), p. 63, the species was redescribed, but nothing added as to its internal structure. It is here stated to be found in the green shales of Cashaqua creek, and in the Hamilton group at Eighteen-mile creek. In the same work, the species *Clymenia Erato* is described (p. 64), and figured (pl. 10, fig. 1). This is of similar character to the *C. complanata*, but is also given without details of interior structure. It is recorded as from the Hamilton group at Geneseo, and at Patterson's creek near Moscow.

The Palaeontology of New York, vol. v, pt. 2, p. 455 (1879), gives what was then known concerning the shell. The sutures are here described in the following terms: "Rising from the axis, they make a gentle retral bend and are recurved toward the aperture from a point about one-third the width of the volution from the umbilical margin, describing a shallow lateral lobe; thence arching more abruptly, they include a more elevated lateral saddle, the apex of which is at a point about two-thirds the width of the volution from the umbilical margin. From this point the septa arch backward, limiting a narrow, acute lobe on the peripheral margin." This description has evidently been derived from the specimen figured upon pl. lxx (fig. 8), which presents an apparently immature manticoceran suture, totally unlike anything observed by us among these forms. This specimen seems to us to be a worn or macerated example of *Mantic. Pattersoni*, in which the wear has been carried inward to the extent of rounding the lobes. It is refigured under the same name in the Supplement to the same work (vol. vii), pl. cxxvii, fig. 2, but without modification of the sutures. In reference to the fossils of the Portage group, it has been usual to refer to *Gon. complanatus*, the very common discoid specimens in which the shales abound. The writer has himself thus identified such specimens* and has also fallen into the error of describing as the suture of this *Gon. complanatus*, that of a macerated *Mantic. Pattersoni*. As it is now evident that such discoidal specimens may represent quite different species, and there is no way of knowing to which of these the original of *Gon. complanatus* belongs, we have felt compelled to set aside the name, or to reserve it against further study of the original whenever that shall have been found.

*Bull. U. S. Geol. Surv. No. 16, pp. 47, 48.

Distribution. In certain of the above references the species *Gon. complanatus* or *Clymenia Erato* is cited as occurring in the Hamilton shales. Thus, of the figures given in Palaeontology of New York, vol. v, pt. 2, that on pl. lxx, figure 6, is stated to be from just below the Genesee shales on Fall creek, Geneseo, Livingston county; figure 7, the original specimen of *Clymenia Erato*, from Moscow, Genesee county. Also, in the Supplement to this volume, published in 1888 (see citation) a figure is given of a septiferous shell from the Hamilton group at Geneseo. Though this is a broadly umbilicated shell, it is evidently not closely related to *Probel. Lutheri*, as shown by its general form and septation. The other specimens from the Hamilton group afford no clew to the internal structure and it is less likely that they represent *Prob. Lutheri* than the distinct though imperfectly known form just specified.

A shade of doubt is cast over all these citations from the facts that these localities are so situated that any of them could furnish specimens from either the Hamilton or Portage formations, and also, because no specimen of this type has been recorded from the Hamilton group where doubts could not fairly arise as to the authenticity of the record, nor has any such been observed by the writer in all the extensive collections from this formation that have come under his examination.

Genesee shales. In its normal adult condition, the species has not been observed in these beds. We have already noticed that the Styliola limestone contains a small shell corresponding throughout to an immature stage of *Probel. Lutheri*, but, so far as our knowledge extends, this shell (*Gephyroceras Genundewa*) does not pass this phyloneanic condition. Still, more complete information may demonstrate that these are the actual young of *Probel. Lutheri* (see page 86).

Portage shales and flags. Especially abundant in the soft shales at Naples, Ontario county, along the Cashaqua creek, Livingston county; less common in the Genesee valley section, though not infrequent further west in Erie county. Fine barite replacements have been obtained from the concretions in the region of Honeoye and Conesus lakes.

Genus BELOCERAS, Hyatt.

This genus was based upon the Westphalian Devonian species, *Gon. multilobatus*, Beyrich (-*Gon. sagittarius*, Sandberger), a discoidal, laterally compressed shell, with broad, peripherally flattened whorls, rather narrowly

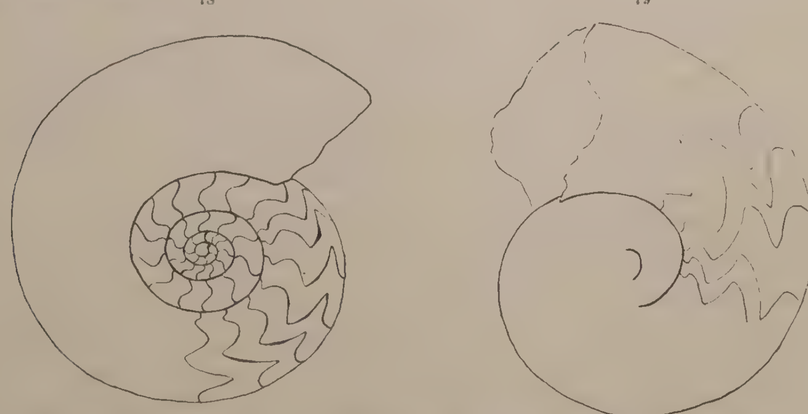
umbilicated, and having a highly subdivided suture consisting of (according to SANDBERGER) not less than fourteen lobes on each ventral quadrant, the majority of these being sharply acute. According to HYATT, these have been derived from the division of the fundamental ventral, lateral and umbilical saddles. The type is evidently an unstable and transitional one; *Beloceras multilobatum* attains the extreme of sutural subdivision, *Bel. Kayseri*, Holzapfel, approaches it most nearly with nine lobes and saddles, while our species, *Bel. iynx*, bears six on each lateral slope. The increase in intensity in the tendency to multiplication of these minor septal divisions is even more forcibly apparent on comparison with the more stable type of PROBELOCERAS (*Probel. Lutheri*).

BELOCERAS IYNX, sp. nov.

Plate VII, Figs. 11–16.

Shell in all external characters, as far as known, indistinguishable from *Probeloceras Lutheri.* It is not so abundant a shell as that and hence its various phases are less known; but in respect to umbilication, ornamentation, form of whorls and mature size there seems at present no means of distinction in the two. The important difference is in the suture, its mature form and successional phases.

78 79



Figures 78, 79. *Beloceras iynx.* Two specimens showing the character of the later septa. x5

The Suture. In its mature condition as shown during the course of the fifth and sixth whorls the suture is zigzagged into three acute saddles and corresponding lobes; an obtuse ventral saddle is a fourth and two small rounded umbilical saddles make six. While all but three of the saddles are acute, only the two umbilical lobes are rounded. This is the ultimate form of the suture and it is virtually acquired at the opening of the fifth whorl. During the third volution and half through the extent of the fourth, the

ventro-lateral saddle, has not yet appeared, but at three and one-half volutions the ventral saddle has become very broad and its division probably immediately follows. At this stage of growth there is, also, but a single sublateral saddle, a lateral and an umbilical lobe; and of all lobes and saddles only the ventro-lateral lobe is acute. At the opening of the third volution the form of the suture is gephyroceran, all auxiliary lobes and saddles being still undeveloped and during the course of the second whorl the suture is distinctly anarcestian. Further than this there is little to be now said with reference to the variations in growth. The stages referred to have been made out largely from immature individuals and it will be observed that, as we have already had occasion to remark, the ephebic condition of the PROBELOCERAS suture does not clearly appear in any of these stages. Better material may show that it is closely approached in the course of the first half of the third whorl before the introduction of the sublateral saddle and while the suture is gephyroceran. Even here its lobes and saddles are rounded, not acute as in the ultimate condition of PROBELOCERAS and BELOCERAS. It is, however, important to note that PROBELOCERAS presents an immature phase of the suture which would agree throughout with such a condition.

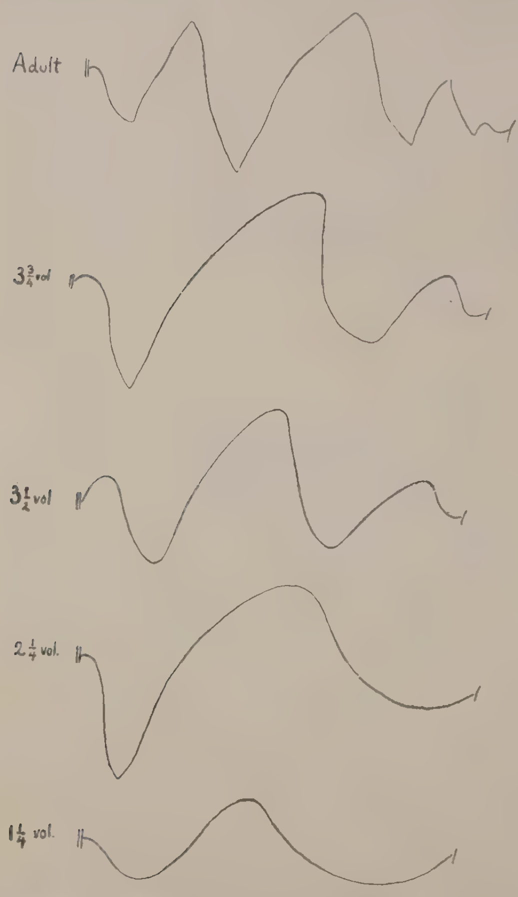


Figure 77. *Beloceras iynx.* **The development of the septal sutures.**

Distribution. *Beloceras iynx* is found associated with *Probel. Lutheri* in the Portage shales and appears to be considerably the less abundant of the two. It has thus far been observed only in localities of the lower part of the formation at Naples.

PROBELOCERAS (?) NAPLESENSE, sp. nov.

Plate VII, Fig. 18.

This is a representative of the GEPHYROCERAS-BELOCERAS series which is intermediate, in suture lobation, between PROBELOCERAS and BELOCERAS. Tentatively it is referred to the former genus, for our observations are restricted to a single specimen which in itself does not justify us in now assigning to the species the generic importance which its characters suggest.

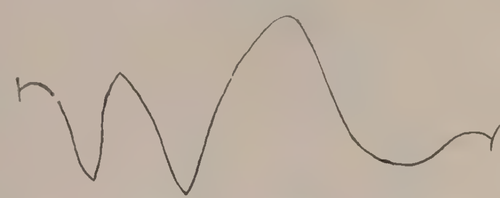


Figure 78. *Probeloceras ? Naplesense.* The adult suture.

In external aspect there are no features distinguishing it from *Probel. Lutheri* and *Bel. iynx*; it has the same degree of umbilication, the laterally compressed whorls and sharply defined hyponomic keel. The ventral saddles are divided by a faint median lobe, the main lateral saddle is well developed, subacute and inclined toward the umbilicus and a narrow, sharp, ventro-lateral saddle is present. The ventro-lateral and lateral lobes are narrow and subacute, and the umbilical lobe broad and rounded.

The species has been found only in the soft shales at Naples, N. Y.

Genus SANDBERGEROCERAS, Hyatt.

The shells for which this genus was erected have lost the manticoceran saddles and lobes by frequent division, are widely umbilicated, the whorls very broad on the venter and covered with costae. The author of the term has pointed out that the essential generic characteristic is the costation of the whorls, the course of the suture in typical species not being unlike that of PROLECANITES.

The two species embraced within this designation by HYATT, *Gon. tuberculoso-costatus*, Sandb., and *Gon. Chemungensis*, Hall, differ from each other in the character of their sutures to this extent, that in the earlier and smaller form (*Gon. tuberculoso-costatus*) lobes and saddles are equally rounded, while in *Gon. Chemungensis*, the lobes are all pointed.

In BELOCERAS, the multipartite suture has both lobes and saddles acute and a much more discoidal, narrowly umbilicated shell.

SANDBERGEROCERAS SYNGONUM, sp. nov.

Plate VII, Figs. 19, 20.

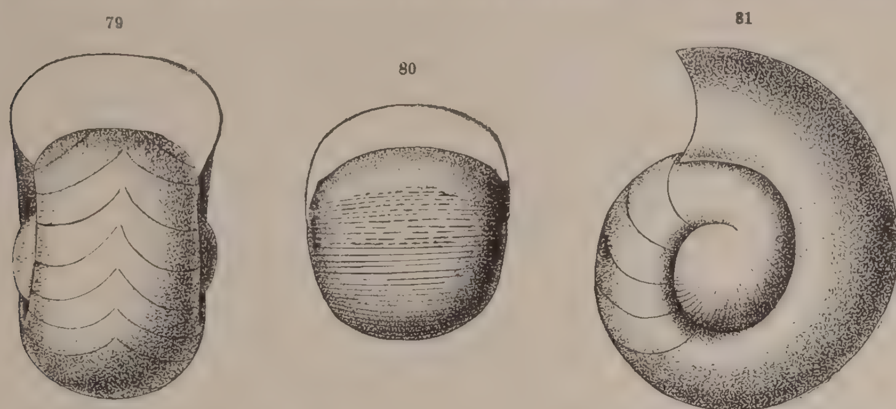
Shell widely umbilicated, with broad and shallow whorls. At maturity six or seven whorls are exposed and the umbilication at this stage equals nearly one-half the diameter of the shell. In cross-section the mature whorl is considerably wider than high, and the inner whorls have this difference greatly increased. The venter is broadly flattened by a duplicate keel, which covers one-half or the entire lateral width of the whorl. This hyponomic area consists of a median convex portion and two very narrow lateral grooves from which it is distinctly separated by a narrow elevated line. Each of the lateral furrows is separated from the sides of the whorl by an elevated ridge.

Ornamentation. Upon the innermost whorls are sharp, elevated concentric lines, which soon become united in small bundles, so that the costate appearance of the whorls shows itself as early as the third volution. Out ward, the size of the bundles increases; on the fifth whorl they begin to modify the surface of the shell itself, and on the final whorls they become ridges, bearing fine, elevated striæ upon their surface and in the interspaces. These ridges or costae have a sigmoid curve, bending forward toward the venter, but they become less prominent the further they retreat from the umbilicus, and on the ventral surface are wholly resolved into striae. Upon reaching the hyponomic area, the striae are sharply recurved over the lateral grooves and continued backward in deep hyponomic festoons over the median area.

Early characters. The protoconch of this species is very large, much the largest of any of the Devonian forms here described; it is ovoid and its lateral extremities project conspicuously beyond the margins of the median and later portions of the first whorl.

It declines in size from its posterior extremity forward, and our material shows that after the appearance of the first septum there is a gradual loss in diameter in the first whorl followed, after minimum diameter is attained, by a slower gain in width. The overlap of the conch upon the protoconch is hence, less at the middle or even at the end of the first whorl than at its beginning. This is evidence quite similar to that observed in more fully represented species, *Mantic. Pattersoni*, *Probel. Lutheri*, etc.

The protoconch is distinctly ornamented nearly to its distal extremity by fine transverse striæ which have not been followed upon the earlier whorls. The projection of the protoconch is always distinctly shown in the umbilicus



Figures 79–81. *Sandbergeroceras syngonum* x 25. Figs. 79, 81. Front and side views of protoconch with first whorl; fig. 79, shows the early septa and the marked lateral protuberance of the protoconch; fig. 81, shows the striations on the surface of the protoconch; fig. 80, represents the protoconch viewed from near its distal extremity, and shows its striated surface.

of a well preserved shell. In one example some of the septa of the first whorl can be made out and these are seen to have a broad sharp ventral lobe and a low, almost direct lateral curvature which may be traced without modification for about a half volution.

The whorl section to the completion of the third volution is very broad and narrow, the venter being quite flat.

The early conditions of the shell are thus seen to be very similar to those of the Styliola limestone species, *Mantic. fasciculatum.*

Although none of the specimens of this rare shell have preserved the adult suture there is little doubt of its being allied to that of *Sandberger. Chemungense* and *Sandberger. tuberculoso-costatum.* The latter is very closely related to this in all other respects, and perhaps a specific difference in the two can be indicated only in the strong costation of the earlier whorls in the European species. The presumption, hence, strongly favors the view that *Sandberger. syngonum* is the American representative of that specific type. Some of the European costate forms like *Gon. tuberculatus*, Holzapfel,* from the upper Devonian of Westphalia, have a manticoceran suture, but also possess a much more discoidal shell and a narrow hyponomic flattening, resembling our species *Mantic. nodifer* much more than that under consideration.

The suture of *Sandberger. tuberculoso-costatum* is shown in the accompanying figure taken from SANDBERGER. That of *Sandberger. Chemungense* is an

* Palaeontographica, xxvii, iii, p. 20, pl. xlv, figs. 7–10.

important step further along toward PROLECANITES. All of the prolecanitoid species are of rare occurrence in the American Devonian; but a few specimens of *Sandberger. syngonum* have been found and of *Sandberger. Chemungense*, Vanuxem, but one has been recorded besides the original specimen.* The earlier species is the smaller in its adult form, more primitive in the shape of its whorls and presumably of its suture. The latter species has been found only in association with species characterizing the earlier faunas of the Chemung formation.

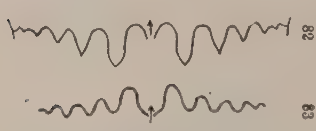


Figure 82, Suture of *Sandbergeroceras Chemungense*, after WALL.
Fig. 83. Suture of *Sandbergeroceras tuberculoso costatum*, after SANDBERGER.

Sandbergeroceras syngonum is from a layer of crinoidal fragments in the lower soft shales of the Portage group at Naples and a single large impression has been found in the bituminous shales constituting the "lower black band" of this group, rocks in which traces of fossils are exceedingly rare. This is also from the town of Naples (Snyder's gully).†

The species of the upper Devonian which have been referred to PROLECANITES, such as *Gon. lunulicosta*, Sandb., and *Gon. Becheri*, von Buch,‡ are but very slightly removed from these forms of SANDBERGEROCERAS. The figures of *Gon. lunulicosta* given by FRECH show very clearly the tendency of the surface ornament to assume the fasciculate character of *Sandberger. syngonum*, though the development of such bundles is obscure and no nodes or ridges are attained. The broad ventral keel is present in all. PHARCICERAS, Hyatt, was based upon another similar species, *Gon. tridens*, Sandb., which HOLZAPFEL and FRECH have placed with PROLECANITES, but which was separated from that genus on the basis of its divided ventral lobe. FRECH's species *Prolecanites triphyllus* is a flat, discoidal shell, wholly unlike the typical forms of the genus in this respect, and in its suture it is more like a SPORADOCERAS than a PROLECANITES.

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* This one has been termed *Gon. Chemungensis*, var. *equicostatus*, Hall, but there seems to us, after comparison of the original specimens very little ground for the distinction.

† This specimen was identified by the writer in Bull. 16, U. S Geol. Surv. (p. 51), as *Gon. Chemungensis*, *variety*.

‡ See HYATT, *op. cit.*, 1883, p. 335; FRECH, Geologie der Umgegend von Haiger, Abhandl. zur geol. Specialk. von Preuss. u. d. Thür. Staat., Bnd. viii, 1887.

Family **Magnosellaridae**, Hyatt.

TORNOCERAS, Hyatt, 1883.

This genus was founded upon the species which is here considered, *Gon. uniangularis*, Conrad. Some recent writers, principally ZITTEL,* FRECH† and HOLZAPFEL,‡ have expressed the belief that TORNOCERAS and HYATT's genus PARODICERAS, founded upon the *Gon. discoideus* Hall, are parallel and equivalent terms and have let one be absorbed by the other. HOLZAPFEL has argued for this construction at some length. There is, however, a notable difference in the course of the mature suture in the types of these two subdivisions, but this distinction has been obscured by the confusion of illustration. This fact was distinctly pointed out by BEECHER,§ in a valuable contribution upon the development of *Torn. uniangulare*, and upon a review of the original material of these two species, it seems to us necessary that *Gon. discoideus* be restricted to shells agreeing with that originally figured in the 13th Ann. Rept. N. Y. State Cabinet of Natural History, p. 98, and reproduced in Palaeontology of New York, volume v, part 2, pl. lxxi, fig. 4, (also figs. 5, 6, 8, 9). This form occurs only, to our knowledge, in the goniatite limestone of the Marcellus shales.

Whatever generic value, therefore, the term PARODICERAS (or *Parodoceras*, which, as FRECH has suggested, is the proper spelling of the word) is to have, must be derived from the characters of this species. At a more recent date than that above cited, FRECH‖ has observed that a difference in these shells will be found herein: That TORNOCERAS has a short living chamber and strongly curving growth-lines, while PARODOCERAS has a longer living chamber (more than one volution), straighter growth-lines and numerous lateral ridges. The term PARODOCERAS has also been lately applied by GÜRICH¶ to certain Devonian species, on the basis of these differences, supplemented by a departure in the internal course of the suture. GÜRICH shows that in *Parodoceras saculus*, Sandb. (sp.) the internal saddle is divided into two, thus making an infrasutural lobe which does not exist in typical examples of TORNOCERAS. In view of these considerations we have re-examined the specimens upon which the genus PARODOCERAS, and its type species (*Gon. discoideus*, Hall) were founded and find the following to be

Figure 84. The course of the adult suture in *Parodocreas discoideum*.

* Handb. der Palaeontologie, vol. 2, p. 418.
Grundzüge der Palaeontologie.

† Zeitschr. der deutsch. geol. Gesellsch. 1887, p. 442.

‡ Das Obere Mitteldevon (Schichten mit Stringocephalus Burtini and Maeneceras terebratum) im Rheinischen Gebirge, p. 80, 1895.

§ Amer. Jour. Sci. vol. xl, p. 72, 1890.

‖ Zeitschr. deutsch geol. Gesellsch., 1893, p. 333.

¶ Verhandl. d. russ. kais. Mineral. Gesellsch. zu St. Petersb., 2d ser. vol. 32, pp. 339 et seq. 1896.

the facts with regard to the points raised: (a) The living chamber may cover though rarely exceed an entire volution; this is also true of *Torn. uniangulare*; (b) the growth lines are curved and indicate a pretty deep hyponomisinus; (c) labial ridges are unknown; (d) the entire course of the suture at maturity is shown in the adjoining figure, and it will be observed that its internal course is undivided as in TORNOCERAS. Moreover, it will be clear that its entire course corresponds with precision to an early sutural condition of *Tornoceras uniangulare.* We are thus compelled to infer that the features cited can not be regarded as determinative of the genus PARODOCERAS. With present evidence the most dependable basis of distinction in these genera is the acceleration of TORNOCERAS over PARODOCERAS in sutural structure.

TORNOCERAS is a genus whose suture is susceptible of considerable variation in the prominence and curvature of its lobes and saddles. This fact was sufficiently shown by the SANDBERGERS in their long list of variant expressions of *Torn. retrorsum* and is again brought out with much force both by KAYSER and by HOLZAPFEL (*op. cit.* pp. 82, 83). The latter especially observes that in the older forms the ventral saddles are very inconspicuous, the lateral lobe flat, while the lateral saddle is abruptly curved. This is the PARODOCERAS condition which that author finds to be an ontogenic phase of TORNOCERAS, his observations thus confirming those of others (HYATT, BEECHER and the writer) and serving to establish the claim of PARODOCERAS to generic distinction. The fundamental forms of TORNOCERAS from the middle Devonian illustrate a progressed condition in which the strength of lobes and saddles is intensified. Among those forms of the genus where there is as yet no angulation of the lateral lobes, all lobes and saddles retaining their rotundity, this increase in curvature is progressive into the faunas of the upper Devonian. The evidence from the European goniatitine faunas agrees with that we have to present, but here we observe the continuation of TORNOCERAS into the fauna of the Choteau limestone of Missouri, as recently made known by S. A. MILLER and W. F. E. GURLEY * where it is represented by a strongly lobed species (*Torn. Jessie*, M. and G.) approaching in its suture our form, *Torn. rhysum.*

KAYSER, in his revision of the SANDBERGERS' determinations of *Torn. retrorsum,* † pointed out the interesting fact that in the earliest and latest forms of German faunas, the lateral lobes are acutely angled while in the species of the middle and especially upper-middle Devonian, these lobes are round. This is finely exemplified in the lowest Devonian species, *Torn. inexpectatum,* Frech, which, as observed by this author, is hardly to be distin-

* Bull. No. 11 of the Illinois State Museum, p. 46, pl. v, figs. 18-20, 1896.

† See KAYSER, Zeitschr. der deutsch geol. Gesellsch. vol 35.

guished from species of the uppermost Devonian. The American species of the genus bring out forcibly another fact pertaining to the time value of variations in the suture. *Tornoceras Mithrax*, Hall, just referred to as the earliest species of our faunas, has acute ventral saddles; this character again appears only among the later forms of the genus, *Torn. peracutum* of the Naples fauna, and is seen also in the *Torn. mithracoides*, FRECH, of the lower upper Devonian of Nassau. In one other species this feature is retained, the *Torn. Edwin-Halli** from the upper Chemung rocks of New York, in which, together with the feature mentioned, there is a notable tendency toward the obsolescence of the lateral lobe, shown in the very gradual passage of the curve of the lateral saddle into that of the adjoining lobe; a feature which seems to be less atatistic than distinctly gerontic.

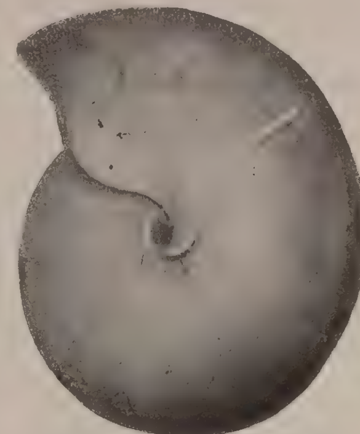

Figure 85. *Tornoceras Edwin-Halli.*

TORNOCERAS UNIANGULARE, Conrad (sp.).

Plate VIII, Figs. 15–18.

1842 *Goniatites uniangularis*, Conrad. Jour. Acad. Nat. Sci. Phila., vol. viii, p. 268, pl. 16, fig. 4.

1860 *Goniatits discoideus* and *uniangularis*, Hall. Thirteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 98, figs. 5, 6, 6 (bis).

1876 *Goniatites discoideus*, Hall. Illustr. Devonian Foss. pl. lxxi, figs. 1, 7, 10–13.

1876 *Goniatites uniangularis*, Hall. Idem. fig. 14; pl. lxxii, figs. 6, 7; pl. lxxiv, fig. 2.

1879 *Goniatites discoideus* Hall. Palaeontology of New York vol. v, pt. 2, pl. lxxi, figs. 1, 7, 10–13.

1879 *Goniatites uniangularis* Hall. Ibid. fig. 14; pl. lxxii, figs. 6, 7; pl. lxxiv, fig. 2.

1885 *Goniatites discoideus*, Clarke. Bull. No. 16, U. S. Geol. Surv. p. 48.

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* *Tornoceras Edwin-Halli*, sp. nov. This rare shell is of moderately large size, highly involute, almost but not quite non-umbilicate. Whorls compressed laterally and otherwise as in normal species of TORNOCERAS. The curve of the suture as exposed over the last whorl is a notable departure from normal expressions of TORNOCERAS, for the lateral lobe and saddle are reduced to a simple curve in which both are nearly obliterated. On the other hand the ventral saddle is strong and acute. The dimensions of this species are shown in the adjoining cut. The specimen is from the Chemung sandstones of Nile, N. Y.

1888 *Goniatites discoideus*, Hall. Palaeontology of New York, vol. v, part 2, Suppl. (= vol. vii), pl. ccxxvii, figs. 11, 12.

1890 *Tornoceras uniangulare*, Beecher. Amer. Jour. Science, vol. xl, pp. 71–75, pl. 1. (=*T. uniangulare*, var. *compressum*).

1895 *Tornoceras simplex*, Holzapfel. Das obere Mitteldevon, etc.; Abhandl. der königl. Preuss. geolog. Landesanst. N. F., Heft 16, p. 95.

This is the only goniatite which has entered the Portage fauna from those preceding it in the state of New York. This is not to say that it contributes an inharmonious element to this exotic association, for the generic, if not also the specific type, is widely distributed in the European Devonian, throughout the middle and upper faunas, as it is here. HOLZAPFEL* has recently regarded this species as a synonym of VON BUCH's *Gon. simplex* (*Gon. retrorsus* of most writers), the determination of whose identity rests upon KAYSER's observations upon one of the specimens labeled by VON BUCH†. While there is, in nearly all structural features, excellent reason for such a conclusion, we are still of the opinion that the New York species is to be held distinct, from the fact that, unlike typical examples of *Torn. simplex*, it is clearly non-umbilicate at maturity. The European species shows a narrow, but nevertheless open and distinct umbilicus at full growth (cf. HOLZAPFEL's figures); this is not the case with *Torn. uniangulare*, in which the umbilicus is not only completely closed at a very early stage, but is frequently calloused and the edge of the stoma is thickened and slightly reflexed at this point, so that it becomes notably prominent.

Figure 86. *Tornoceras uniangulare.* **The stomal lip at the umbilicus expanding to cover the umbilical cavity. Taken at early ephebic stage. x 25.**

Like the European *Torn. simplex*, the American *Torn. uniangulare* is a species of great vertical range, but it seems to have been of a distinctly more stable type. It first appears in the Marcellus shales where it abounds; occurs plentifully in the shales of the Hamilton group, in the Tully limestone, the Styliola limestone and locally in the Portage group. In all of these formations, the commonly occurring specimens are of small or medium size, but individuals of much larger dimensions occur in all. The representatives of the species which have been afforded by the Marcellus and Hamilton shales are seldom of such a quality as to indicate possible variations of form and structure, but the more favorably preserved material from the Styliola limestone and the Naples beds, indicate that such variations occurred.

* Obere Mitteldevon im Rheinischen Gebirge, p. 95, 1895.

† Zeitschr. der deutsch. geol. Gesellsch. vol. 24.

Normal mature form. The mature shell has a body chamber extending for not less than an entire volution. The normal form of the species is discoidal, compressed laterally, with an evenly rounded venter and is well expressed in figures 6 and 7, on plate 72, Palaeontology of New York, vol. v, part 2. The whorl section in full-grown shells is, naturally, larger dorso-ventrally in proportion to its width, than in earlier growth stages and thus the more commonly occurring miniature specimens show a greater rotundity of whorl. It is, of course, impossible to establish a definite expression of the convexity of the whorl of the normal *Torn. uniangulare*; the adult itself may vary slightly in this respect, but there are extremes in this regard which we have excluded from the species, designating them as distinct varieties.

Development of the shell. The early history of the shell has been very nicely worked out by Prof. C. E. BEECHER.* So far as our material has permitted we have reviewed and, in the main, corroborated these observations. BEECHER's investigations were based upon pyrite specimens from the Hamilton shales at Wende station, Erie county, N. Y., shells which, after an examination of specimens kindly supplied by Mr. BEECHER, we regard as representing the variety *compressum*, as described more fully hereafter. The nature of our material representing early growth stages, is mostly of a different and more fragile preservation, and some of the points already established by the author cited, are not clearly expressed in our barite replacements, particularly the course of the earliest septal sutures.

The Protoconch. The primitive shell when placed in comparison with the protoconchs of the other goniatites here described is distinguished by its

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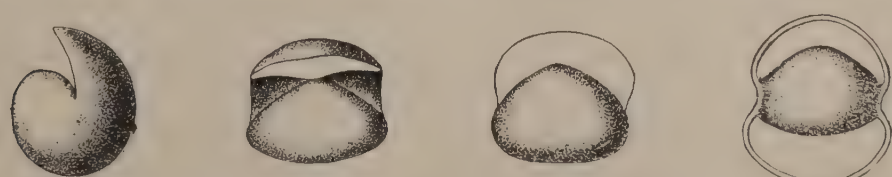

Figures 87–90. *Tornoceras uniangulare.* Views of the protoconch. Fig. 87. Side view; figs 88, 89, views of the distal extremity; fig. 90, view near the distal extremity. x 25.

peculiar shape. Viewed from its distal surface it presents a distinctly triangular outline, the shell coming to a sort of blunt apex at the middle of its extremity and sloping thence at the sides to the low, broadly curved venter. This angulated contour of the distal surface is continued forward over the rest of the protoconch but rapidly loses its prominence, so that the entire

* On the Development of the Shell in the genus Tornoceras, Hyatt. Amer. Journ. Science, *ut cit.*

angulation appears to be confined to the first half of the protoconch. This characteristic shape is well displayed in the accompanying figures.

Form of the earlier whorls. The whorl at the commencement of the first volution is very narrow and crescentiform in section, but its relative width is nearly doubled before this volution is completed This continued rapid increase in dorso-ventral width renders the first three or four volutions highly convex, the second and third being very rotund. Gradually there follows a lateral compression of the whorl lessening its rotundity and eventuating in the elongated lunuliform section of the mature shell.

Umbilication is minute but distinct until the close of the third volution. Its maximum, however, appears to be not at the commencement of the overlap

Figures 91, 92. *Tornoceras uniangulare.* Lateral and ventral views of a shell of two volutions, showing the open umbilicus, the course of the septa and the incipient ventral ridge. x 25. Fig. 93 A young shell smaller than that represented in figures 91, 92, but with less umbilication. x 25.

of the protoconch by the first whorl, but at the end of the primary volution. Thenceforward there is a regular decrease of umbilication until it disappears at the very early age specified by the projection of the recurved edge of the stoma which eventually forms an erect projecting callous filling the umbilicus.

Sutures. At maturity the suture has broad and very shallow magnosellarian saddles, a lateral lobe with an abrupt slope on the umbilical side, but gently depressed on the venter to form a saddle of about the same size although less strong than the lateral lobe; the ventral lobe is narrow and acute. In mature forms where the septa are close together (a normal feature) the umbilical slopes of the ventro-lateral lobes of adjacent septa are almost contiguous and their upward slopes often present the appearance of a continuous revolving line. This effect is lost in earlier growth stages where the septa are more distant. The dorsal course of the suture is even more simple than its ventral course; it makes a single low saddle similar to the magnosellarian saddles but longer and deeper, and a rather deep dorsal lobe.

In its history the suture passes through simple changes. BEECHER has shown that the first suture is an almost direct line without evidence of ventral lobe, and that on the second septum this lobe is indicated and accompanied by a slight forward lateral curvature forming primitive saddles. When the shell has a diameter of 3 mm. we find that the suture shows a division of this primitive saddle by a broad ventro-lateral lobe, thus giving rise also to the lateral saddle. At 3.5 mm. diameter, the prominence of the lateral lobe and this tendency constantly progressed render the lobe more conspicuous and deepen the large saddles. Progress in the form of the suture hereafter consists in a more pronounced development of these curves, the narrowing of the lateral saddles and increase in convexity of the outer slope of the lobes.

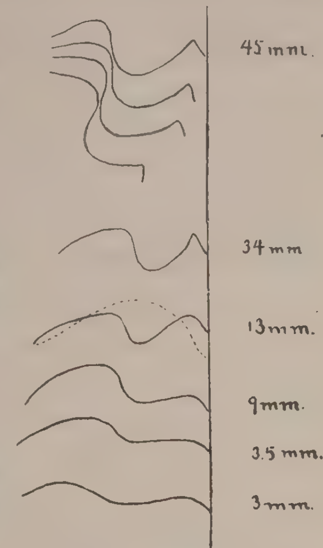

Figure 94. *Tornoceras uniangulare.* Development of the septal sutures.

Ornamentation. The fine transverse striations of the protoconch which have been observed by BEECHER are not present in our specimens. The ornamentation of later growth stages, though almost invariably obscure, consists of fine concentric lines which are elevated, sharp and simple over the earlier whorls but soon become fasciculated and obsolescent so that in the mature condition the whorls are virtually smooth on the exterior, though sharp internal casts may retain traces of the curving striae and also show obscure lateral revolving bands which are not represented on the exterior. The external striae make a broad anterior sweep from the umbilicus and with a rather abrupt and acute turn recurve into a wide and deep hyponomic sinus. The narrow anterior curves which bound this sinus lie in two revolving furrows which are plainly visible on the third and fourth whorls, where they outline a ventral ridge, but ridge and furrows become rapidly obscured on later whorls. Very young shells in the second and third volutions sometimes bear transverse labial ridges, which are never seen in adults of American species but appear commonly among European specimens of this genus. The character of the inner shell layer, or "Runzelschicht," in this genus has been illustrated by both HALL * and HOLZAPFEL.† In the umbilical region where the shell has become calloused this layer bears fine, implanted or anastomosing raised lines concentric to the umbilicus. These

* Palaeontology of New York, vol. v, pt. 2, Suppl. (=vol. vii), pl. cxxvii, fig. 12, 1888.
† Das obere Mittel-devon im Rhein. Gebirge, 1895.

may cover one-third of the lateral slope of the whorl, but gradually become broken up into shorter, irregularly branching, discontinuous, often comma-shaped lines having a general direction toward the periphery. At the periphery they become more strongly elevated and have their larger axes all lying in the direction of revolution.

Distribution. *Tornoceras uniangulare* appears first in the bituminous shales of the Marcellus division and is distributed rather sparsely throughout the fauna of the Hamilton shales. In the Tully limestone it is rare, in the shales of the Genesee it is seldom seen, though it abounds in the Styliola limestone on Canandaigua lake and at Middlesex, Yates county. In the Naples beds it occurs more sparsely than in the prenuncial fauna, but frequently appears in the calcareous concretions of the lower part of the group in the Honeoye lake valley, occurring also in the shales in Naples valley. West of the Genesee valley the species is of rare occurrence in these beds. Specimens of large size are far less frequent in the Intumescens-fauna than in the Marcellus and Hamilton shales beneath. No specimen has been observed from the Portage group with a diameter exceeding 50 mm., but the State Museum possesses an imperfect shell from the Marcellus shale at Le Roy, whose diameter was not less than 160 mm.

The Portage fauna of Cortland and adjoining counties contains this species with others, together derived from the Hamilton fauna beneath.

TORNOCERAS UNIANGULARE, var. OBESUM, var. nov.

This variety is characterized by the much greater thickness and tumidity of the whorls. The feature is recognizable in both young and adult forms and at any given stage of growth it is noticeably distinct in this respect from the normal specific form at the same stage. It is undoubtedly an instance of a long continuance of immature conditions in the normal, serving as a differential in the adult.

This form is of rare occurrence and has been observed only in the concretions at Naples and on the lake Erie shore.

TORNOCERAS UNIANGULARE, var. COMPRESSUM, var. nov.

The specimens from the Hamilton shales at Wende Station, Erie county, upon which BEECHER based his observations of development changes, are laterally compressed shells with a subangular periphery. Even in early stages of growth, at the third volution, when the normal shell is very rotund, this compression is observable. These characters are accompanied by a clear

definition of the peripheral band upon volutions where, in the normal, they have totally disappeared. It is important to observe that BEECHER'S measurements of the protoconch in this variety make it of considerably greater size than we find to be the case in the normal Naples forms of the species. According to that author, the transverse diameter of the protoconch is 1.06 mm.; we find it to be .77 mm. Most of our figures have been made from isolated protoconchs, but whatever doubt might arise as to their form or identity is dispelled by the adjoining figure, a section of a mature shell through the protoconch. This figure has been reduced somewhat more than the others

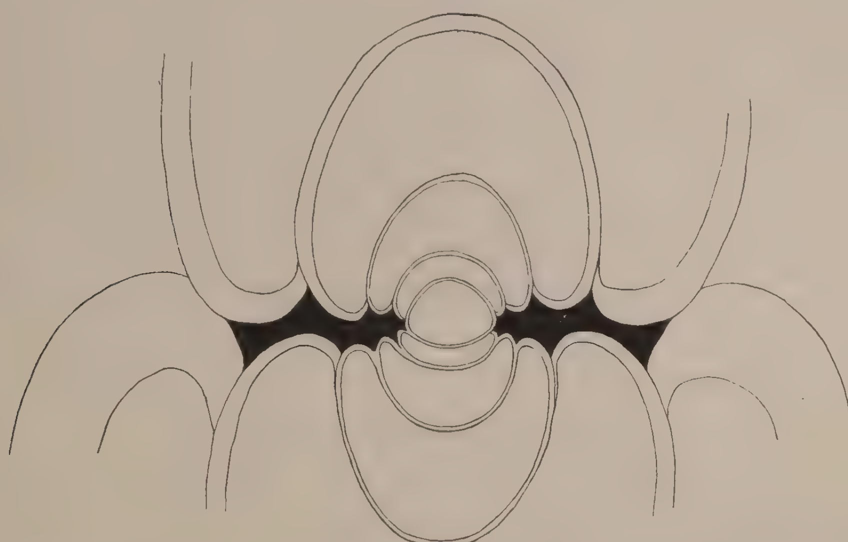

Figure 95. *Tornoceras uniangulare.* Section through the protoconch of an adult shell, showing the modification of whorl section, the early increase and final decrease and total extinction of umbilication. x 18.

on account of its size, but shows that the actual dimensions of the protoconch are as elsewhere given. Representatives of this variety, *compressum*, are common in the Styliola limestone in association with the normal.

A laterally compressed shell from the horizon of the Hamilton group at the Falls of the Ohio, *Torn. Ohioense* (figured without description under the name *Goniatites discoideus*, var. *Ohioensis*, Hall and Whitfield (Twenty-seventh Annual Report N. Y. State Mus. Nat. Hist., pl. xiii, figs. 18, 19, 1873), may prove on future investigation to be a similar variety.

We may observe here the interesting fact, that the varietal differences similar to these here noticed within the limits of *Torn. uniangulare* have been recently defined by GÜRICH,* within the species *Torn. circumflexus* Sandb.; namely, the varieties *applanata* and *incrassata*. As the species

* *Op. cit.* p. 338, pl. xiii, figs. 5, 8.

themselves are most closely related, similar tendencies to departure from the normal in provinces so remote, as are evinced by these varieties, are worthy of note.

TORNOCERAS PERACUTUM, Hall (sp.).

The original fragment of the species described and figured in Palaeontology of New York, vol. v, part 2, p. 463, pl. lxxix, fig. 8, was taken from the Portage rocks at Ithaca. The species was one of large size, closely umbilicated and has a suture differing from that of *Torn. uniangulare* in its prominent loop-shaped lateral lobes and acute ventral saddles. This is shown in the accompanying figure and it will be seen that the outline is a natural extreme of development from the suture of the typical TORNOCERAS. The species may be directly compared in size and form of suture to *Torn. mithracoides*, Frech, from the upper Devonian of Nassau.*

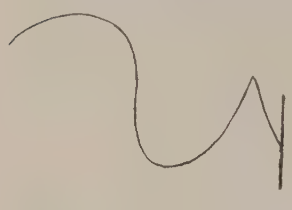

Figure 96. *Tornoceras peracutum.* The adult suture.

TORNOCERAS BICOSTATUM, Hall (sp.).

Plate VIII, Figs. 4–13.

1843 *Goniatites bicostatus*, Hall. Geology of New York; Rept. Fourth Dist., p. 246, fig. 107–8 (p. 245).

1860 *Goniatites bicostatus*, Hall. Thirteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 103, figs. 19–20.

1876 *Goniatites bicostatus*, Hall. Illustrations of Devonian Fossils, pl. lxxii, figs. 8–10; pl. lxxvi, fig. 1.

1879 *Goniatites bicostatus*, Hall. Palaeontology of New York, vol. v, pt. 2, p. 450, pl. lxxii, figs. 8–10; pl. lxxiv, fig. 1.

1885 *Goniatites bicostatus*, Clarke. Bull. U. S. Geol. Surv. p. 49.

The original figures of this species given in the Report on the Fourth Geological District of New York, show that the specific name was based upon the strong revolving hyponomic ridges, but both these figures and those subsequently given in volume v, part 2, Palaeontology of New York, indicate that all illustration of these features has thus far been based upon compressed specimens in which the broad, flat venter has been turned to one side and hence the revolving ridges been made to appear as though they appertained

* FRECH, Geologie der Umgegend von Haiger bei Dillenburg (Nassau), p. 30, figs. 1a, α, b, β, 1887.

to the lateral slopes instead of being distinctly ventral. Further, the shell has been represented and described as distinctly umbilicate at large size.

The species is of rare occurrence in the Genesee and Naples regions and appears only in very diminutive form. The described specimens are recorded as found along the lake Erie shore and it is from this region that our specimens, also, have been obtained.

Adult characters. At maturity the species seems seldom to surpass a diameter of 25 mm. It is discoidal in form, with a broadly convex or flat venter and the umbilicus is closed. We shall presently observe that the obliteration of umbilication is affected only in the final volution, so that the removal of the shell of the outer whorl will expose the inner volutions and give the shell an umbilicate aspect. About the ventral periphery runs a pair of low revolving grooves, one on either side, without which are rather low hyponomic ridges.

The *ornament* at this stage consists of fine and crowded or, sometimes, sharp and more distant concentric lines which curve broadly backward over the lateral slopes and then sharply forward on the hyponomic grooves and in a deep linguiform festoon backward upon the venter.

The *septation* is different from that of *Torn. uniangulare* only in the greater prominence and isolation of the lateral lobe.

Immature Growth-stages. The Protoconch. Although we have not been able to isolate the embryonic shell, it will be seen from our drawing both of

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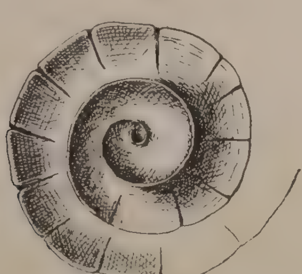

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Figures 97, 98. *Tornoceras bicostatum.* Fig. 97. An external impression of the inner whorls, showing the very small protoconch, the gradual expansion and diminution of the nepionic shell and the distant subequal varices of the neanic stage. Fig. 98. Lateral view of the protoconch, nepionic and early neanic whorls. The surface does not retain the fine ornament shown in fig. 94, and the varix on the second whorl is probably a labial ridge. x 25.

lateral and sectional views that it is exceedingly small; thus similar to, but even more extreme in this respect than *Torn. uniangulare.* It may to some degree, be concealed by the broadening of the first whorl but it is not clear that this is the case.

Post-embryonic stages. The swelling of the conch with the opening of the nepionic stage is abrupt and noteworthy. The neck of the protoconch is very narrow, but from this point outward the shell widens, attaining greatest width at about a half-volution, where it is five or six times as wide as at its commencement. Thence it gradually contracts and with the completion of a full volution it has not more than two-thirds of its maximum width. This contraction of diameter is followed by a more gradual increase. Thus the three stages of nepionic growth are clearly evident.

Whorl-section and umbilication. Figure 99, which is a complete vertical section of a mature shell, serves to show the relatively great breadth and shallowness of all early whorls. All are broad on the venter but the flattening of the ventral periphery is not so strongly brought out in this section as in many of the young shells themselves; the definition of this feature, however, is one that is perfected with growth, becoming most pronounced at or just before maturity.

It will be observed that umbilication is broad and complete through at least four volutions, that there is a rapid loss of umbilication and increase of overlap in the following volution and complete closure with the ensuing whorl. The phenomena thus shown, are a repetition on a more striking scale, of those already shown to exist in *Torn. uniangulare.*

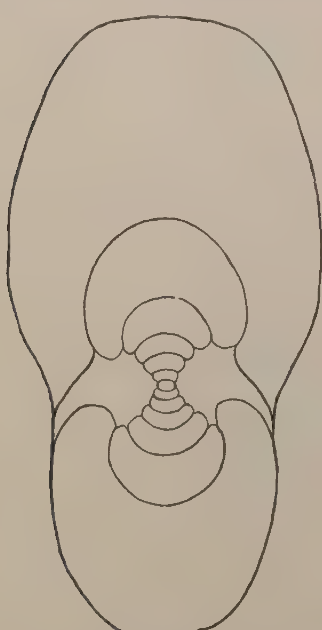

Figure 99. ***Tornoceras bicostatum.*** **An ephebic shell sectioned vertically through the protoconch, showing the contour of the whorls and the final extinction of early umbilication. x 5.**

Ornamentation. The earliest varical lines appear in the course of the second volution, are distant, simple and strong. Their course on the venter before the third volution has, however, not been determined. During the second volution, these varices become sharply elevated and sometimes strongly thickened on the lateral slopes, make a broad, backward and then a sharp forward curve, and recurve deeply on the venter. The distinguishing mark of these young shells is the strength of these striations and their distance from each other.

With regard to the septation of earlier stages no observations have been made that are altogether satisfactory.

Tornoceras bicostatum is represented in our collections by specimens from Big Sister and Farnum creeks, in Erie county, near Angola, and along the shore of lake Erie in that vicinity; also, by occasional specimens from he soft shales near Son Yea, Livingston county, and at Naples.

TORNOCERAS RHYSUM, sp. nov.

Plate VIII, Fig. 14.

This rare species is of small size, narrowly but distinctly umbilicated to an ephebic growth stage, and the surface of the shell is characterized throughout by its low, broad corrugations, curving retrally on the lateral slopes of the whorl, making a very pronounced and acute forward bend ventro-laterally and thence at a sharp angle curving backward over a well defined venter where their strength is so increased that they present the aspect of a series of festoons. This unusual ornament gives the species a very striking expression. The whorl section is somewhat less compressed than in normal forms of *Torn. uniangulare*, and is distinctly more convex than in *Torn. bicostatum*. The lobation of the suture is more sharply developed than in *Torn uniangulare* and is very similar to that of *Torn. bicostatum*. The magnosellarian saddles are long and prominent, the ventral saddles and ventro-lateral lobes deep, subequal and symmetrical; the ventral lobe is deep and acute.

Figure 100. *Tornoceras rhysum*. The adult suture.

Our material representing this species fails to give us further details of its character and development phases. It has been found only in a single calcareous concretion from the soft shales at Java village, Wyoming county, associated with *Gephyroceras cataphractum*. The species is readily distinguished from the other forms of TORNOCERAS here described, by the character of its ornamentation, and from *Torn. bicostatum* in particular, by the absence of the sharply defined peripheral band.

General Observations on Tornoceras.

It has already been observed that, in defining the genera PARODOCERAS and TORNOCERAS, Professor HYATT regarded the latter as a probable derivative of the former in the line of ANARCESTES.

As to this more remote origin of TORNOCERAS, there are some considerations which need to be carefully weighed. The oldest species of TORNOCERAS known in American faunas is the *Torn. Mithrax*, Hall, from the Corniferous limestone (upper lower-Devonian); a large, closely umbilicated and, in respect to suture, fully developed form. Following this appear next in order, *Parod. discoideum*, *Torn. uniangulare* and *Torn. Ohioense*, in the faunas of the Hamilton group. In this country, also, ANARCESTES is not known before the opening of the middle Devonian and is represented by only a single species, *A. plebeiformis*, Hall (very closely allied to *A. lateseptatus*,

Beyr.), which is restricted to the lower part of the Marcellus shales (lowest middle Devonian). Likewise AGONIATITES, abundant in the goniatite limestone* of the Marcellus beds and occurring sparingly through the higher strata of the Hamilton group, is not yet known to be of greater age.

In the German Devonian faunas, TORNOCERAS does not appear so early with reference to these other genera, but it is stated by FRECH† to be present in the lower Devonian limestone of Cabrières (France) and also to be represented in the lowest Devonian of the eastern Alps (Wolayer Thörl) by two species, *Torn. inexpectatum* and *Torn. Stachei*, occurring in association with *Anarcestes lateseptatus.*‡

We may look upon these facts as essentially the sum of present evidence as to the historical relations of TORNOCERAS with these simpler genera. They do not justify an assumption that this genus has been directly derived from either ANARCESTES or AGONIATITES. TORNOCERAS takes no place in the line of phases in part contemporaneous and in part successive, which we have now seen to constitute the series from AGONIATITES through GEPHYROCERAS to PROBELOCERAS, BELOCERAS and PROLECANITES. With PARODOCERAS it is outside this line of development. Its generic characters indicate an accelerated development firmly established and long continued; a departure from a more distant source in which the origin of ANARCESTES and AGONIATITES may also be sought.

Family **Bactritidæ,** Hyatt.

Genus BACTRITES, G. Sandberger.

Since the determination by BRANCO, that a certain specimen from the Wissenbach slates, referred by him to the genus BACTRITES, bears an egg-shaped, erect protoconch similar to that possessed by *Goniatites compressus*, Beyrich, and other representatives of the genus MIMOCERAS, authors generally have inferred a close genetic connexion between BACTRITES and the goniatites, by way of MIMOCERAS and ANARCESTES. The additional evidence pertaining to the character of the early stages in this genus, which was brought out by the writer in the *American Geologist*, for July, 1894§, and which will be here presented with amplification, does not fail to confirm this inference, while it

* This well marked horizon which has long been distinguished by this term, would be more precisely designated by the name *Agoniatites limestone*, as its characteristic species is the *Agon. expansus*, Vanuxem. The adoption of this term is in accordance with the best usage and is the more justifiable because of the occurrence of "goniatite limestones" at various horizons in the Devonian and Subcarboniferous.

† Zeitschr. d. d. geolog. Gesellsch., vol. xxxix, p. 406, 1887.

‡ *Ibid.* p. 733, pl. xxviii, figs. 9–11.

§ The Early Stages of Bactrites, *op. cit.* vol. xiv, pp. 37–43, pl. 2.

emphasizes the orthoceran origin of the genus;* nor does it seriously militate against the cautious statement of HYATT:† "It is quite possible that BACTRITES of the Devonian may be a degraded form of MIMOCERAS, but in that case the latter is also a degraded form of ANARCESTES or transitional between it and BACTRITES. * * The straight BACTRITES-like young of some forms of ANARCESTES, the gyroceran young of others of the Goniatitinæ and the gyroceran adults and young of MIMOCERAS, indicate the derivation of the Goniatitinæ to have been from Silurian straight shells similar to BACTRITES, if not directly from that genus itself."

In the correlation of present evidence relating to the ontogeny of BACTRITES, it will, perhaps, be helpful in explaining apparent discrepancies in the result, to keep in mind the fact that the single protoconch ascribed by BRANCO to BACTRITES (species not determined) is from a lower Devonian horizon, while the numerous examples here recorded are from now well known and typical species, *B. gracilior* and *B. aciculum*, appertaining to a much later (lower upper-Devonian) fauna.

Specimens of BACTRITES are common throughout the Intumescens province of New York, but because of their slender pencil-like cones, good examples of adult shells are very rarely found. The young stages which have been studied, indicate that the two species differed in the size of the protoconch and the degree of expansion of the tube, but the outcome of these differences in the adult is not in every respect perfectly clear. The majority of all of these young shells seem to agree among themselves and possess many of the characters which have been ascribed to SANDBERGER'S species, *Bactrites gracilis*, a shell which is found in certain facies of the Intumescens fauna, as for example, in the Iberg fauna of the Hartz mountains. To this species the writer was at one time disposed to refer one of the New York forms. With fuller knowledge of this shell it now seems necessary to acknowledge its specific difference.

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* In Catalogue of Fossil Cephalopoda in the British Museum, Part III, by FOORD and CRICK, 1897, these later results have escaped notice.

† Genesis of the Arietidæ.

BACTRITES GRACILIOR, sp. nov.

Plate IX, Figs. 1–16.

1891 *Bactrites*, sp. nov. Clarke. Neues Jahrb. für Min., Bnd. 1, p. 166; Amer. Geol., August, p. 95.

1894 *Bactrites* cf. *gracilis* (Sandberger), Clarke, Amer. Geol. vol. xiv, p. 37.

In its adult form this species has a somewhat less gradual expansion of the conch, usually a less length and a less elliptical cross section than its associate *B. aciculum.* The shell when quite uncompressed is sometimes subcircular in section, as is well shown by the larger barite replacements, but specimens from the calc-nodules may have their ellipticity of section somewhat exaggerated. The angle of divergence of the shell walls in the final parts of the adult would indicate a complete length of about 180 mm. for an average individual.

Body-chamber. The final chamber in two individuals retaining the aperture, has a depth of 30 mm. At about the middle of its length it swells slightly and thence gradually contracts forming a decided constriction. At the aperture the shell is expanded and wider than in any other place, so that the direct slope from the aperture is broadly funnel-shaped. The margin of the aperture may be slightly oblique and curve backward a little at the sides, but no specimen exhibits this feature in its entirety.

Air-chambers. The septal chambers decrease in relative depth from early growth stages, and though this modification is slight, it appears to be uniformly gradual. In the adult condition we count four air-chambers in a length of 10 mm. This may be contrasted with the early chambers where in a distance of 5 mm. from the protoconch there are ten septa. Yet this statement of *relative* decrease in depth of these chambers is true.

Septa. The septa are quite regularly convex, considerably oblique, sloping toward the dorsum. The septum meets the wall of the conch at a very small angle and thus opens a possibility of apparent slight variation in the course of the suture as preserved on the internal cast. The dorsal lobe is well marked and on internal casts almost invariably exaggerated by the exfoliation of the thin edge of the septal cast. The sipho and siphonal funnels are not in any case or at any period of growth, distinctly marginal but are bounded dorsally by a clear moiety of the septum. This is an important fact which should be emphasized in any attempt to determine the phylogenic status of this genus. The "dorsal lobe" of BACTRITES is virtually a condition due to the detachment of the edge of the shallow septal cast and

Figure 101. Diagrammatic figure showing the relation of the siphonal funnel to the inner shell wall.

with it a part or all of the siphonal collar which is frequently recumbent on the conch or in contact therewith except at its distal extremity. Our delicate replacements place this fact beyond question. On the sides of the shell the suture makes a gentle backward curve and rises again but not so far on the antisiphonal surface.

Ornamentation. It may be observed by examination of our figures of young shells, that the surface is crossed by fine, concentric, oblique lines closely crowded together. These lines are rarely seen in the adult shell unless under the most favorable preservation. With advance of age and growth, such lines are combined to form, or are replaced by, obscure broad and low oblique ribs which, like the others, slope backward to the dorsum. These are especially noticeable on the body-chamber but are, nevertheless, often so obscure as to be seen only in oblique light. These features, as well as the contour and septation of the shell, are precisely those ascribed to *B. gracilis* by SANDBERGER, but we observe here in addition, with favorable preservation, a secondary ornament in final growth stages; fine, vertical, subequal lines, not seen below the body-chamber.

Early Growth Stages. The Protoconch. This is a bubble-shaped body, frequently somewhat unsymmetrical or directed to one side, very broadly sessile upon the end of the shell tube, from which it is separated by a constriction varying somewhat in depth. We have here presented a number of figures of this primitive shell which indicate a possibility of variation in prominence and size of this body. To a very large degree such differences are due to various modes of preservation. Thus figure 5 represents an internal pyrite cast which shows the asymmetry of the protoconch and the deep constriction where it is attached to the conch. Figure 4 is a pyritized shell broken and showing the internal cast. These two specimens show some difference in size of the protoconch; the apparent difference in the contour of the conch is due to difference in point of view. Figures 1–3, 6 are barite replacements of the shell itself which show some difference in the distinctness of the protoconch; and figure 7 is an internal barite cast which may possibly belong to the other species, *B. aciculum.* Several of these specimens show in their continuation the septal features characteristic of this genus.

First septum. Not infrequently the delicate protoconch is broken and such specimens have afforded means of determining the fact that the opening of the sipho in the first septum is distinctly lateral. None of the specimens studied have shown trace of the siphonal cæcum.

Initial conch. The tuberous swelling of the shell-tube directly above the protoconch is a very striking feature of these shells. Several of our figures show this feature; on others it is less distinctly marked and this difference is in a large part, if not wholly, due to the fact that this expansion is greater at the sides of the shell than on the dorso-ventral surfaces, and figures in which it is less pronounced are of the lateral aspect of the shells. This increase in diameter is quite abrupt from the protoconch upward for a distance of two air-chambers, and then more gradually decreases. While the surface of the protoconch is smooth, a fine ornamentation begins with the ananepionic stage. This consists in delicate crowded striations crossing the surface with an inclination to the dorsum.

In my earlier paper on the Early Stages of Bactrites, written before the nepionic growth-phases of MANTICOCERAS and TORNOCERAS as heretofore explained, had been made out, this swelling of the primitive conch was spoken of as an "ONCOCERAS-like expansion, for its form, usually unsymmetrical, suggests that genus and may afford a key to its phyletic position." Its apparent lack of symmetry we have just explained. We now regard the existence of this inflation of the nepionic shell the most forcible argument yet advanced for the affiliation of BACTRITES with MANTICOCERAS, PROBELOCERAS and hence with the goniatites generally. For the full force of this argument the reader is referred to the detailed account of the expanding and contracting nepionic shell in those genera, as given on preceding pages. Again, we may find in the evident asymmetry of the protoconch in BACTRITES, with reference to the conch to which it is attached, and in the slightly asymmetrical position of the protoconch upon the conch, as indicated in *Manticoceras Pattersoni* and *Probeloceras Lutheri*, additional evidence of genetic connexion.

The early stages of this species occur in greater abundance and better preservation than those we have referred to the species *Bac. aciculum.* It is important here to emphasize distinctly the similarities and differences between these primitive stages and that described by BRANCO as belonging to BACTRITES, for the reason above stated, that upon the latter determination is based the generally accepted phylogeny of the goniatites. The Wissenbach specimen, which is not known to have been duplicated, carried, besides the protoconch, five air-chambers, in a part of which the lateral position of the sipho was shown; for this reason it was with propriety referred to BACTRITES.

The form of the protoconch is shown in the accompanying outline taken from BRANCO's figure. It is elongate vertically or egg-shaped, slightly unsym-

metrical, attached to the conch above with a rather broad and gradual constriction. We have no clue to its actual size, the author having given no dimensions, but the figure indicates that with relation to the size of the conch it is considerably larger than the protoconch in *B. gracilior.* This specimen, further, shows little evidence of the nepionic expansion so well marked in *B. gracilior* and *B. aciculum.*

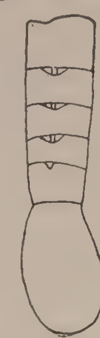

Figure 102. A reduced copy of BRANCO'S figure.

With regard to the shells of *Bactrites gracilior* we know not only their protoconch and early stages but their mature characters and life history. There can be no doubt that these represent a typical example of the genus BACTRITES, as described by SANDBERGER, and a species very closely allied to his own *B. gracilis.*

The apparent discrepancies in these protoconchs referred to BACTRITES may in some measure be accounted for by our knowledge of the goniatites. We have observed that a difference in the size of the protoconch is possible within the limits of a given genus; though this is not great in any progressed genus such as MANTICOCERAS, nor is it accompanied by any noticable variation in form. In the genus TORNOCERAS, notable for its long duration, wide diffusion and abundant development through the Devonian, a genus which is simple in its septal development but shows evidence of acceleration in some other respects, there is a marked difference in the size of the protoconch in examples of the early *Torn. uningulare* and the late *Torn. bicostatum.*

We have shown in the foregoing and following pages the possibilities of variation in actual size of the protoconchs in some of the goniatitine genera and it will be observed that the protoconchs in the early and simple genera AGONIATITES and ANARCESTES are of colossal size when compared with such later and progressed genera as MANTICOCERAS, TORNOCERAS and PROBELOCERAS. At the same time the progressed genus SANDBERGEROCERAS also possesses so large a protoconch that we dare not assume unusual size in this body to be an unfailing index of simplicity in the species, though it be undoubtedly true in general, and this fact of the presence of larger protoconchs in earlier and simpler species of goniatites may afford an explanation of the conspicuous difference in size in the Wissenbach protoconch of BACTRITES and that of the later *B. gracilior.*

To account for the apparent difference in form, no explanation suggests itself. Our figures of *B. gracilior* show some variations in the dimensions of this structure which are not readily explained unless they be ascribed to the action of resorption, but none of them presents an ovoid form like that of the Wissenbach shell.

For the absence in the latter of the nepionic expansion of the conch so notable in our species of BACTRITES, we can offer no further explanation than that afforded by a comparison with the goniatites here studied. This expansion is seen in TORNOCERAS, MANTICOCERAS, PROBELOCERAS, etc., but not in the same degree in each genus, nor, again, to like degree in members of the same genus. Thus it is much the more conspicuous in *Torn. bicostatum* than in the earlier *Torn. uniangulare;* it is clearly, though not conspicuously, developed in *Mantic. Pattersoni*, but we have given a figure of *Mantic. intumescens* in which it is very prominent.

We should have no justification in concluding from the foregoing observations that the Wissenbach specimen is not a BACTRITES, on the contrary the very differences which have been pointed out as existing between this early shell and the typical BACTRITES, *B. gracilior*, are in themselves evidences of time and ontic changes within the same genus.

Localities. *Bactrites gracilior* occurs in the Styliola limestone on Canandaigua lake and at Middlesex. In the normal fauna it is widely distributed through the shales and calcareous nodules, but becomes less common in the arenaceous beds. It has been found at various localities in Yates, Ontario and Livingston counties, in the Genesee valley and in Wyoming county, and also in Erie and Chautauqua counties. Specimens which can be referred to this species with certainty are more numerous in the eastern counties than in those bordering on lake Erie, where their place seems to be largely taken by the other species, *B. aciculum.*

BACTRITES ACICULUM, Hall (sp.).

Plate IX, Figs. 17–22.

1843 *Orthoceras aciculum*, Hall. Geology of New York; Report on the Fourth District, p. 243, fig. 4.

1879 *Coleolus aciculum*, Hall. Palaeontology of New York, vol. v, pt. 2, p. 187, pl. xxxii A, figs. 11–15.

To this species, whose representatives, as above cited, are flattened specimens from the shales of the Genesee and Portage beds, I refer a shell distinguished from *Bactrites gracilior* in its decidedly more elliptical conch section in all stages of growth and probably also in its smaller protoconch and more slender nepionic shell. It is of so much less frequent occurrence than *B. gracilior* that it is not easy to indicate from our material other specific characters than those mentioned.

Of the specimens which afforded the basis of the specific descriptions cited, there is none which in itself conclusively demonstrates to which of these two species it appertains. They are crushed and so changed as to have lost, for the most part, their original ornament and to have rendered it impossible to determine their specific characters with precision. It has seemed desirable, however, to retain the specific name. The figures on Plate IX show the nature of the protoconch and early shell, and also the size attained by the conch at maturity and its strongly elliptical section.

Localities. *Bactrites aciculum* is found in the Styliola limestone on Canandaigua lake. Whether the specimens found commonly in the black shales of the Genesee beds, above and below the Styliola limestone and referred to in the original description, belong to this species it is not now possible to say. A similar shell abounds in the soft shales of the Naples beds and uncompressed specimens occur in the calcareous nodules in Erie, Ontario and Livingston counties. The young shells figured are barite replacements from the vicinity of Honeoye lake.

The Phylogenic Status of Bactrites.

We have already quoted the opinion of Professor HYATT given in the "Genesis of the Arietidæ," as to the significance of this genus, and his later expressions upon this point are somewhat more precise though of the same intent. Before citing these opinions, we may here direct brief attention to a protoconch described by the writer from the fauna of the Styliola limestone. This was discussed prior * to my studies of the Early stages of Bactrites and was originally referred to as the Protoconch of Orthoceras. In the figures 23–25, on Plate IX, I have redrawn this body with the same degree of enlargement as the illustrations of the same part in BACTRITES. Comparison of these figures will show considerable similarity in form but a wide difference, first, in actual size and, again and of primary importance, in the position of the sipho. It was upon the central position of the latter in this unique specimen, contrasted to its lateral position on the first septum in BACTRITES that I tentatively regarded this protoconch as appertaining to ORTHOCERAS, notwithstanding the evidence adduced by Professor HYATT to show that in ORTHOCERAS the protoconch was represented only by a wrinkled and shriveled remnant. With regard to this body HYATT, in his more recent and remarkable paper, entitled the Phylogeny of an Acquired Characteristic,† observes that this

* American Geologist, vol. xii, p. 112, 1893.
† Proceedings Amer. Philos. Society, vol. xxxii, No. 143.

"form certainly has the characters of an ORTHOCERAS, but the protoconch is large and like that of the Ammonoidea. The shell may be transitional from ORTHOCERAS to BACTRITES, but it is probably not a typical form of ORTHOCERAS." At first thought this suggestion seemed to me untenable; it was hardly probable that a long period of careful exploitation of this fauna would have produced only this single protoconch as the representative of a generic form transitional between ORTHOCERAS and BACTRITES; and yet it is conceivable that such differences as are here indicated by the young may be totally extinguished in the later growth stages so that the mature form of the species in question may be before us, though present knowledge does not enable us to recognize it. Professor HYATT's wise expression thus throws additional emphasis upon the orthoceran affiliations of BACTRITES. The present view of Professor HYATT with reference to the status of BACTRITES is clearly expressed in the following words from the work last cited (p. 362), "BACTRITES is a perfectly straight form, similar to the members of the Goniatitinae in all important characteristics, especially the siphuncle and septa, and it also has, like the young shell described by CLARKE, and all the coiled Ammonoidea, a comparatively large protoconch, as demonstrated by BRANCO * * This same genus includes straight cones like *Bactrites* (*Orthoceras*) *pleurotomus* Barr. (Syst. Sil. pl. 296), which are undeniably transitions to true ORTHOCERAS in their striæ of growth and position of siphuncle. There is, therefore, convincing evidence in the structures of these Silurian shells that the Ammonoidea, with their distinct embryos, arose from the orthoceran stock and passed through a series of forms in times, perhaps, preceding the Silurian, which were parallel to those characteristic of a number of genetic series among Nautiloidea, viz., straight, arcuate, gyroceran and nautilian."

Although this inference as to the origin of BACTRITES from orthoceran ancestry was to a considerable degree based upon the characters of the primitive shell in that genus as described by BRANCO, yet such additional facts as we have been able to bring out do not fail to confirm it. We find strong indication of orthoceran affiliation first, in the globular protoconch and its similarity to the *Orthoceras*-like shell of the Styliola limestone; secondly, in the character of the sipho which is truly intra-marginal in BACTRITES. On the other hand, no true goniatite has the sharp constriction about the entire periphery at the close of the protoconch, although it is approached by MIMOCERAS. The early erect shell in MIMOCERAS, and the swelling of the nepionic shell in BACTRITES which is reproduced in several genera of goniatites, TORNOCERAS, MANTICOCERAS must be regarded as fortifying the goniatitine affinities of the genus.

II. CLYMENINÆ.

Family Cyrtoclymenidæ, Hyatt.

Genus CYRTOCLYMENIA (Gümbel), Hyatt.

GÜMBEL, in 1863,* proposed a division of the *Clymeniæ* into groups, one of which, the *Cyrtoclymenia* was intended to include those having a simply curved lateral lobe. In completing the definition of the group and erecting GÜMBEL's divisions to the value of genera, HYATT characterized the species of CYRTOCLYMENIA as having depressed semi-lunar whorls (this is true only of the earlier stages of the typical species, *C. angustiseptata*, Gümb.) and both ventral saddles and lateral lobes rounded.

CYRTOCLYMENIA NEAPOLITANA, Clarke.

Under the name *Clymenia neapolitana*, the writer described, in 1892,* the only species of CLYMENIA yet known from North American faunas. Since the date of that description some additional specimens of the species have been obtained which, though not adding materially to our knowledge of the development history of the shell, have shown a more general diffusion than was then known. The species has been found only as barite replacements and as the most fully developed specimens are of comparatively small size, we may still be in ignorance of the final stages in the growth of the shell. The adult shell is laterally compressed to a moderate degree, the outer whorl being comparatively narrow on the venter and subsagittate in section. It is widely umbilicated, the number of whorls not exceeding six in any observed specimen. The later whorls have a narrow, flattened periphery which may be concave in final stages, and this flattening is well defined by revolving lateral grooves.

The ornamentation of the shell is highly characteristic; the younger whorls bear distant lamellar festoons which, when perfectly retained, rise into short, tubular, disunited spines, abutting against the surface of the next later whorl. These gradually disappear near the beginning of the fifth whorl and become resolved into fine concentric growth lines.

The development of the shell. *Protoconch.* The primitive shell is transverse and ellipsoidal and though its lateral extremities project but little from the margins of the first whorl, there is an evident contraction at the neck of the protoconch which sets it off from the whorl. This form of the

* *Ueber Clymenia*; Palaeontographica, vol. xi.
* Amer. Jour Science, vol. xliii, pp. 57–63.

protoconch agrees fully with that ascribed by BRANCO to the only other species of the genus in which the primitive shell has been observed (*C.* cf.

Figures 102–104. ***Cyrtoclymenia neapolitana.*** **Fig. 102. The protoconch. x 25. Fig. 103. Side view of the protoconch with portion of the nepionic shell x 25. Fig. 104. Similar view of another specimen showing the striations extending to the neck of the protoconch. x 25.**

undulata, Münster),* but it is a notable fact that the size of this shell in *C. neapolitana* is very much greater than, not far from thrice, that of the European species. In view of this fact not infrequent among the Goniatitinæ, we quote the expression of HYATT, that "the whole range of the transformations of the Goniatitinæ are paralleled in this short series" (Clymeninæ). BRANCO cites as an important feature of the CLYMENIA protoconch, the absence of depressions at its neck such as occur in all ammonoids, and which HYATT has construed as remnants of the umbilical perforation. We can not say that our specimens clearly substantiate this as a feature characterizing the group. These depressions may possibly be somewhat more obscure in *C. neapolitana* than in its associated goniatites, but not to such a degree as to attract attention without previous suggestion. The protoconch is much narrower at its distal extremity than on the opposite surface, which appears to be rather broadly flattened. This is shown in views represented in figures 102–104.

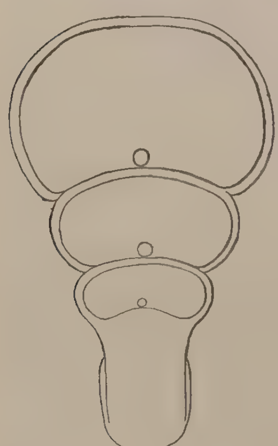

Figure 105 ***Cyrtoclymenia neapolitana.*** Sections of the early whorls. x 25.

The Early Whorls. The cross-section of the first whorl shows its narrow anarcestian outline, a form which is only very gradually lost by the increasing definition of the ventral flattening, so that the vertical elongation of the whorl section manifests itself rather rapidly after the close of the fourth volution. The second and third whorls are broad-backed and rounded, the narrow peripheral flattening manifesting itself first upon the fourth whorl, occupying the median portion of a broad ventral curvature.

* Palaeontographica, vol. xxvii, pl. vii, fig. III.

In the *mature whorls*, the fifth and sixth, the cross-section, as already observed, becomes similar to that of the associated discoid species of goniatites, *Probeloceras Lutheri*, *P.* (?) *Naplesense* and *Beloceras iynx*, though less elongate and with a narrower peripheral flattening.

The Suture. We have not been able to determine from our material the character of the first suture. BRANCO has recorded it as a simple asellate curve, while the second suture has a broad ventral lobe. At two and three-quarters volutions, *C. neapolitana* has a broad and deep, but acute, ventral lobe, and a broadly curved lateral lobe, while the lateral saddle is narrower, transecting the ventro-lateral shoulder of the whorl. On the dorsal side of the whorl is a deep and narrow median lobe and a shorter and obtuse dorso-lateral lobe.

At three, four, and four and one-half volutions the sutures show a gradual increase in the relative size of the ventro-lateral saddle and the lateral lobe, and in the mature suture the former has become broader and deeper than the latter; the ventral lobe also appears to be minutely divided at its apex forming a ventral saddle. On the dorsal side the dorso-lateral lobe has become acute with a sinuous outer curve and the dorsal lobe is very narrow and sharp.

The Sipho. BRANCO has observed that the position of the sipho at the first septum in *C.* cf. *undulata*, Münster, is ventral; this we have also found to be the case in *C. neapolitana*, without having been able to determine the mode of subsequent change in position. It is clearly evident that the sipho becomes dorsal in its position in the course of the first volution. As to the continuity or discontinuity of this tube, a feature upon which GÜMBEL based the main division of the *Clymeniæ*, our material affords no evidence.

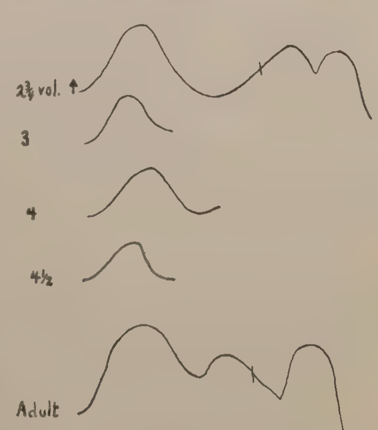

Figure 106. *Cyrtoclymenia neapolitana.* Development of septal sutures.

Ornamentation. The protoconch has shown no trace of surface ornament but the first whorl is covered with close, transverse, elongated lines. During the course of the second whorl appear the distant curved lamellar processes which take the form of a varix with its concave surface projected forward, expanded, and when fully preserved, almost enclosed at the anterior margin. These varices have their greatest height at the dorso-lateral angles of the whorl and abut against the surface of the succeeding whorl. They have either not extended over the ventral surface of the whorl or have become resolved

into fascicles of striae, and upon overgrowth of the whorls, are completely resorbed. They occur normally at intervals, regularly increasing with the growth of the whorls, so that there are about the same number, 9–11, on each whorl. Their effect upon the later whorls is clearly marked, as at their contact with such whorls the growth of the latter is obstructed so that the umbilical margin of the whorl is crenulated or festooned, the edge extending downward in the interval between the varices. Over the fifth whorl the varices are lost, apparently becoming resolved into fine concentric lines which make a broad concave curve forward, forming a narrow tongue-shaped lobe at the shoulder of the whorl, thence being reflected into a narrow hyponomic curve upon the flat periphery.

Distribution. This species has been found in the calcareous concretions in the vicinity of Honeoye lake, Ontario county and to the westward as far as Conesus lake. It has not yet been seen in the Naples region, although it is associated with species abundant there; *Mantic. Pattersoni*, *Probeloceras Lutheri*, *Palæotrochus præcursor*, etc. Its horizon in the Portage formation is the lower or shaly part of the series where all the species of the *Intumescens* fauna are most fully developed.

To the especial geologic interest in the presence of CLYMENIA in this fauna, reference has been made in connexion with the original description of this shell. Notwithstanding the various expressions assumed by this genus, it has shown itself, wherever found in all its other occurrences, to be one of the most reliable indices of the uppermost Devonian, so that the Clymenia-fauna is a well established upper terminal in the Devonian sections of Europe and Asia. The investigations of KAYSER, MÜNSTER, GÜMBEL, RICHTER, TIETZE, FRECH, SIEMIRADSKI, STUR, STACHE, HOERNES, KARPINSKY, TSCHERNYSCHEW, PHILLIPS, MCCOY, WHIDBORNE, HÉBERT, all establish this time-value for the genus. But in its only known American occurrence the genus fails to correspond with its position in the transatlantic sections. This fact is less surprising than it would be if the genus here had attained any great differentiation or variety of expression. Its single species is found with a fauna of such species as that with which it is associated in the region (Westphalia and Fichtelgebirge) of its most rapid evolution.

It is, however, a significant fact that this exiled representative of the genus has a certain goniatitine aspect and is one of the forms in which the typical characters of the genus are not fully attained, as shown in the simplicity of its suture Still in many of its structural features, its whorl-section at maturity, its suture and the peculiar ornament of its immature whorls, it is to be directly compared with the *Cyrtoclymenia spinosa*, Münster.

THE RELATION OF THE GONIATITINE ELEMENT OF THE NAPLES FAUNA TO THE SEDIMENTS IN WHICH IT IS INVOLVED.

From the habitude of living cephalopods it has been inferred by recent writers, of whom we may specially cite J. WALTHER,* that the ammonites, and we may properly conclude, the goniatites likewise, were animals which crept about over the sea bottom by the agency of their tentacles. "NAUTILUS," says WALTHER, "does not, as commonly assumed, swim as nekton in open sea nor does the animal travel about as plankton at the surface. On the contrary NAUTILUS is a benthonic animal, which crawls about on the sea-bottom;" * * only "the empty NAUTILUS shell floats on the surface. The animal of SPIRULA has a sessile benthonic habit, and its empty shell is, also, so constructed that it floats on the water surface. * * * The same is true of SEPIA." Granting that this habit of life was likewise that of the extinct cephalopods (and with present knowledge there is no justification for a contrary assumption), we must concede the great force of WALTHER's arguments in so far as they go to indicate the very great caution required in interpreting the meaning of occurrence among the ammonoids. If the vast majority of these superabundant fossils are, in pursuance of this argument, transported shells floated, as one may say, out of their facies, and dropped in sediments whereon they had not lived and among organic species with which their relations are wholly posthumous, the palaeontologist, in determining when these ammonoids are within their own proper fauna, has before himself a host of problems of the utmost delicacy.

We believe that the influence of this doctrine may easily be carried too far. Abundant cases may be cited in which no doubt can arise as to appertinence of ammonoids to the sediments in which they are contained and the fauna with which they are associated, and lest this fact be overlooked in the application of WALTHER's arguments, that author has himself emphasized it and cited instances of long continued existence and propagation of ammonites upon the very sediments in which they are involved.

The ammonoids of the Naples beds bear sufficient demonstration in themselves that they have lived and died in these sediments. And this is doubtless true notwithstanding the fact that the sediments are largely arenaceous and were deposited in comparatively shallow water, and the equally

* Einleitung in die Geologie als historische Wissenschaft; und Ueber die Lebensweise fossiler Meeresthiere (Zeitsch. d. d. geolog. Gesellsch. vol. 49, Haft 2, 1897).

notable fact that the closest parallel to this fauna is involved in highly calcareous sediments; those of Martenberg, in Westphalia.

The figures given upon our plates and pages are sufficient evidence of the fact that shells retaining the aperture unbroken and all fine ornaments in a perfect condition are not of infrequent occurrence. In many such cases, especially those expressing earlier growth stages and thus possessing the most fragile shells, these have been derived from calcareous concretions which represent the segregation of the lime element in the sediments. These, with other instances of maturer unbroken shells are demonstration that they have escaped the play of the waves and violence of the tides to which, in transportation, they must have been subjected. The pretty sharply defined localization of the goniatite species in different parts of this province is evidence against transportation. To these facts we have already referred; *Tornoceras bicostatum* rarely extends east of the Genesee river; *Torn. uniangulare* as rarely west therefrom; *Manticoceras Pattersoni* is represented in the western region by *Mantic. rhynchostoma; Probeloceras Lutheri* is much more profusely represented east than west of the Genesee, while *Beloceras iynx* has not been observed west of that meridian.

While the evidence is conclusive that this goniatitine element as well as other organic elements of the normal Naples fauna, is not a mechanical invasion, a congeries of flotation, but is in harmony with its components in mode and direction of derivation (except as a few particular instances may be cited), there are, on the other hand, excellent reasons for regarding the prenuncial Intumescens fauna, that of the Styliola limestone, as due to transportation from some adjoining province not yet known to us. This thin nodular stratum, largely composed of STYLIOLINA, is intruded into highly bituminous beds of argillo-siliceous shales. There are placoderm fishes and land plants, with ammonoids, gasteropods, lamellibranchs and crinoids of Intumescens-zone types, embedded among millions of the pelagic, planktonic STYLIOLINA; and all alike impregnated with the bituminous matters which so effectively characterize the Genesee shales. In such organic and inorganic surroundings no goniatite could have lived.

THE ORGIN OF THE GONIATITINE ELEMENT OF THE NAPLES FAUNA.

The data here brought forward to show the intense individuality of the Naples fauna, in the New York series of geologic formations, will be greatly fortified by a completer knowledge of its lamellibranchs and gasteropods. Such remarks, therefore, as are here made upon the derivation of this fauna, are for the present intended to have no wider application than to the element which we have been considering.

It has been observed in the earlier pages of this paper that no evidence of the Intumescens-fauna has been recorded in this country outside of western New York. Since that statement was put in type the writer has received a copy of volume vii of the annual report of the Iowa Geological Survey (1897), where, in a list of species contained in the upper Devonian Lime Creek shales of Cerro Gordo county, is cited (p. 168) "*Goniatites* sp." Upon application to state geologist Professor Samuel Calvin, the author of the paper immediately concerned, on the "Geology of Cerro Gordo county," the writer has been permitted to examine the specimen referred to, which, it may be added, is stated by Professor Calvin to be the only observed example.

The fragment is but a part of a shell, but the outer whorl shows the septa with perfect distinctness. It is a *Manticoceras intumescens* approaching very closely the *Pattersoni* subtype.

This fact loses none of its interest from the nature of the associated fossils. The fauna with which it occurs was first noticed by Professor Hall in 1858;* and since then lists of the species have been given by Professor Calvin, the most complete being that in the work above cited. There is a remarkable agreement in the constitution of this Lime Creek fauna and the Devonian fauna occurring at High Point, in the township of Naples, N. Y., this agreement largely being in species which are not as yet known to occur in other horizons or in intervening localities.†

With reference to the character of its constituent fossils, this High Point fauna has properly been looked upon as the horizon of *Rhynchonella* (*Pugnax*) *pugnus* and a representative of the Chemung brachiopod fauna of New York, though several of its species, common to the Lime Creek fauna, have not elsewhere been found in the later Chemung faunas. The position of the High Point beds is 500–600 feet above the final recorded appearance of the Intu-

*Geology of Iowa, vol. 1, part 2.
† See Clarke, Bull. No. 16, U. S. Geol. Surv. pp. 72–76, 1885.

mescens fauna in the Naples valley. In accordance with the recent observations mentioned in our introductory chapter, the stratigraphic position of these beds appears to be the same as that of the typical and original Portage sandstones of the Genesee valley. Below the High Point beds true Chemung species are scattered through 400 feet of strata.

In whatever light we may look upon the occurrence of *Mantic. intumescens* at Lime Creek, a thousand miles from its only other manifestion in the United States, it is at least a remarkable fact that it appears there in association with a peculiar brachiopod fauna, reproduced elsewhere only in western New York and which lies in the stratigraphic horizon of the Portage sandstones; an horizon which, in the Genesee valley, still carries the Intumescens-fauna.

There is still another indication of the presence of the Intumescens-fauna in North America. Mr. J. F. WHITEAVES, palaeontologist to the Geological Survey of Canada, cites a goniatite from Hay river, forty miles above its mouth, latitude about 60° N.; "a cast of the interior of three chambers of the septate portion of the shell of a species of *Goniatites* [not otherwise determined] in which only the lateral lobes and saddles are preserved, each ventral lobe being completely obliterated by weathering."* The figure given of this worn fragment shows, beyond reasonable doubt, that the fossil is a *Manticoceras intumescens*, the abrasion to which it has been subjected having rounded the lobes and reduced the lateral saddle in an altogether usual manner. Dr. WHITEAVES' investigations record a list of species from the same locality which indicate, some middle Devonian affinities, others the presence of the Cuboides-fauna (*Hypothyris cuboides, Orthis striatula*) and still others the presence of a fauna later in the New York succession, that of the Chemung group, represented by *Spirifer disjunctus, Pugnax pugnus, Schizodus Chemungensis.* Indeed the list leads to the inference that either a complete differentation of the stratigraphic distribution of these species has yet to be made, or that the occurrence is of similar nature to that presented by the well known Iberg fauna of the Hartz mountains, in which middle Devonian, Cuboides and Intumescens zone index fossils are commingled. A similar inference with regard to the fossils recorded by the same writer from the Ramparts of the Mackenzie river is not unfair. *Pugnax pugnus* and other lower upper Devonian species occur with *Stringocephalus Burtini.* The author refers to the presence in the various localities cited by him in the Mackenzie river basin, of ten species present in the Iowa Devonian (Lime Creek beds and

* The Fossils of the Devonian Rocks of the Mackenzie River Basin; in Contrib. to Canadian Palaeontology, vol. 1, 1891, p. 245, pl. 31, fig. 5.

Independence shales), and present evidence shows the occurrence of *Manticoceras intumescens* in both.

The facts cited afford evidence of a feeble representation of the fauna of the Intumescens-zone in Iowa and the far north-west, but without the association of species characteristic of that fauna in its most specialized development as shown in western New York and in Westphalia. On the other hand, they indicate that this single index fossil, *Mantic. intumescens*, will prove to be involved with a fauna of quite different facies, as in many of its European occurrences; Devonshire, the Hartz, the Urals.

At a later opportunity we may take up for consideration the hypotheses which have been put forth with regard to the dispersion of our upper Devonian faunas. They are serving a temporary purpose in the absence of facts and wiser fancies.

But for the Intumescens-fauna alone, meager as the extrinsic evidence is, it suffices to indicate the strong probability of an invasion into its New York province from the west and northwest. Intrinsic evidence is to the same intent; the wedge-like interpenetration of the Otselic fauna at the east of the Intumescens province is sufficient proof. At its incoming the fauna seems to have been weak in the goniatitine element and herein to have rapidly developed great strength and diversity. The present evidence indicates that the goniatite element itself is accelerated. Nothing of it is known within 800 miles of its New York province. It must have entered its province in simple form; otherwise, with so varied an aspect as that here portrayed, it should have left a clearer trace behind. The acceleration of many of its species we have also noted.

The evidence before us shows to how high a degree the confined sea wherein this organic association flourished had become a center of variation, and even of origination of organic types.

EXPLANATION OF PLATES.

PLATE I.

Manticoceras Pattersoni, Hall (sp.).

(See Plates II and IV.)

Figure 1. The young shell up to the end of the ananeanic substage; showing the protoconch, the smooth surface of all nepionic substages and the abrupt introduction of simple varices in the neanic stage. x 10.

Figure 2. The young shell at 2¼ volutions. This is an entire shell in a metaneanic condition, with the aperture and stomal callous preserved. The varices are very strong at this stage and alternate with notable regularity. The aperture is parallel to the varices which cross the whorl without hyponomic curve. x 10.

Figure 3. A complete shell at 2½ volutions, with broad, direct varices reflected at their tips; metaneanic substage. x 10.

Figure 4. A still more progressed phase of this substage with a duplication of the secondary varices. 2¾ volutions. x 10.

Figure 5. A shell of about the same number of volutions but evincing a more progressed condition in its finer and more numerous varices. This feature is especially clear upon the last one-third volution. The shell is entire. x 10.

Figure 6. A somewhat oblique view of a shell in the same stage as the last, showing a slight hyponomic recurvature of the varices on the final whorl. The stomal callous is exposed for a half volution by the breaking away of the shell to the first septum, which shows that the body chamber at this growth stage is relatively short (compare figs. 10 and 12). x 10.

Figures 7, 8, 9. These are shells of 3–3½ volutions, which have entered the paraneanic substage. They are all entire shells, except for a slight breaking of the stoma, and all show the stomal callous. They evince progress in growth, first in the fasciculation of the fine varices and sequentially in their reduction to uniform size; likewise in the increasing hyponomic curvature. From the close of this stage onward, the surface ornament becomes progressively reduced to a series of uniformly fine lines with strong hyponomic curvature.

These figures also show marked increase in the vertical diameter of the final volution accompanied by increased lateral compression. x 5. All the specimens figured above are from the calcareous concretions of the Naples beds in the vicinity of Honeoye lake, N. Y.

Figure 10. A mature shell of the proportions attained by specimens of ordinary occurrence. This is an internal cast of about 4 volutions and is approximately complete in length. The form of the suture is ephebic throughout the final 1 volutions. The outer whorl is laterally compressed and subsagittate in section (see front view of this specimen, plate IV, fig. 16). Natural size. From a concretion in the soft shales at Naples, N. Y.

Figure 11. Transverse section of a mature shell, a part of whose interseptal cavities are filled with deposits of black and white crystalline calcite and the others with calcareous matrix of red and green tints. There is some difference apparent in the septal intervals.

Figure 12. A similar section of a smaller shell showing the length of the habitation chamber.

The last two specimens are from the goniatite concretionary layer in Parrish gully, Naples.

MANTICOCERAS TARDUM, sp. nov.

(See Plate VI.)

Figure 13. A complete, unbroken young shell, showing the continuation of equal varices throughout the entire neanic stage. Although growth has progressed to nearly three volutions, the ornament is ananeanic compared with *Mantic. Pattersoni*. x 10. Honeoye lake, N. Y.

MANTICOCERAS SIMULATOR, Hall (sp.).

Figure 14. The original specimen showing the rounded interior lobe which is metephebic in *M. Pattersoni*. Natural size. Near Ithaca, N. Y.

GONIATITES.

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PLATE II.

Manticoceras Pattersoni, Hall (sp.).

(See Plates I and IV.)

Figure 1. A transverse section of a small specimen showing marked irregularity, for a short period, in the depth of the septal chambers.

Figure 2. A shell with ephebic suture, retaining a rather strong surface ornament.

Figure 3. The protoconch, nepionic shell and a portion of later growth much enlarged.

Naples beds, Naples.

Figure 4. Internal cast of ephebic shell.

Naples beds, Honeoye lake.

Manticoceras oxy, sp. nov.

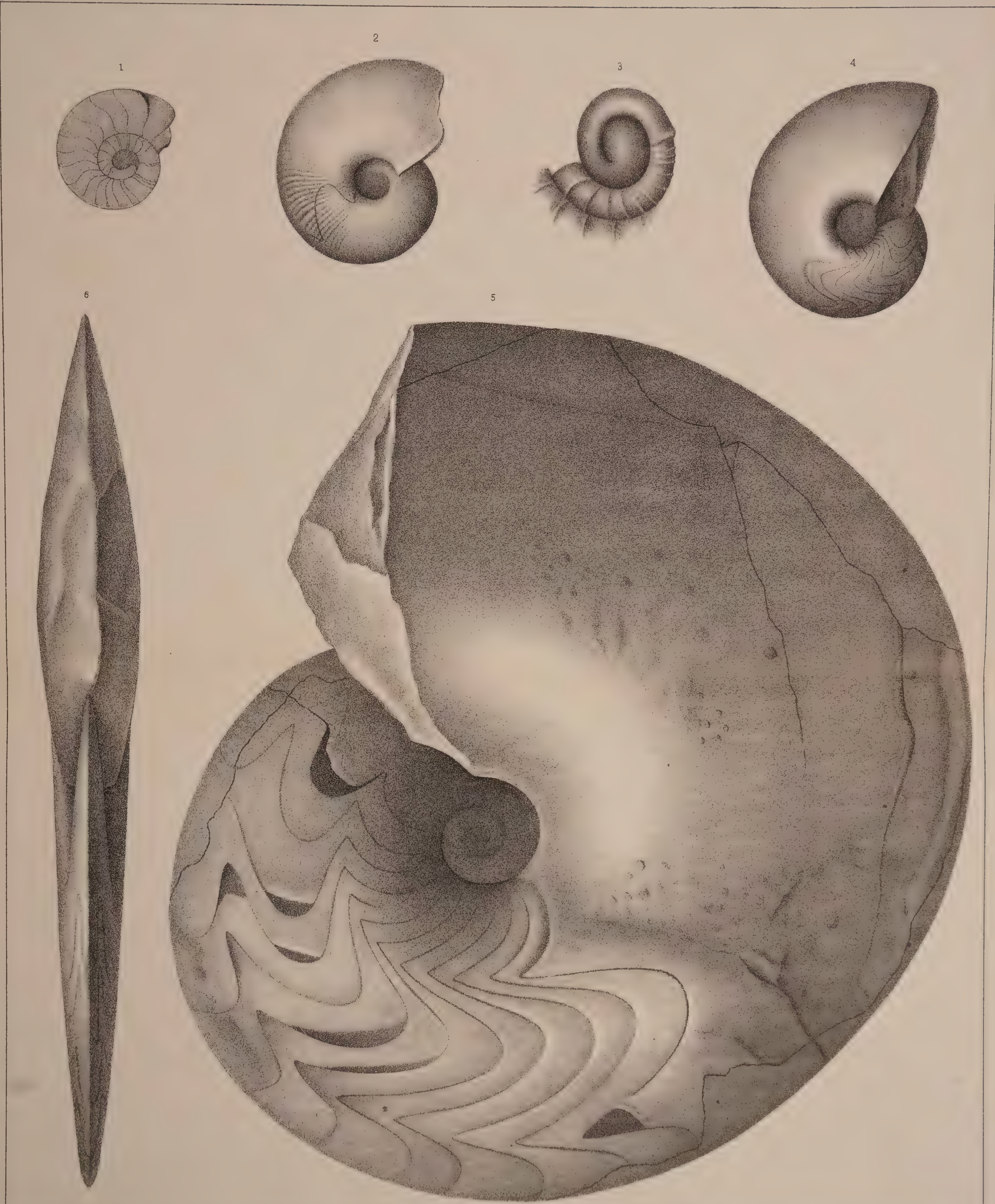
(See Plate III.)

Figure 5. A rather small ephebic specimen with extreme *Pattersoni* sutures.

Figure 6. Front view of the same, to show the sharply carinate venter.

Lower Portage falls of the Genesee river.

GONIATITES.



G. B. Simpson del.

Wynkoop, Hallenbeck, Crawford Co. State Printers, New York and Albany

PLATE III.

MANTICOCERAS OXY, sp. nov.

(See Plate II.)

Figure 1. A sculpture cast of the body whorl of a large shell, believed to be of this species. It retains a considerable part of the aperture and shows it to have possessed a broad auriculate expansion, blunt at the extremity. The surface shows a few broad lateral undulations of surface ornament. To the internal surface of this body chamber were attached numerous Orbiculoideas whose shell substance is partly retained while that of the goniatite has been entirely removed.

From the higher Portage sandstones on East hill, Naples.

Figures 2 and 3. A fragment of what must have been a very large individual of this species; showing the carinate venter and the extreme curvature of the ventro-lateral lobe and saddle.

From the upper sandstones of Caulkins gully, Naples.

Figure 4. A fragment of *M. Pattersoni* or *M. oxy* which shows the extreme effect upon the aspect of the sutures, of maceration before or secondary changes after fossilization. Specimens of this kind occur frequently upon the thin flagstones and show every variation in the form of the suture from the extreme here presented to the normal *Pattersoni* suture. In this example nearly one-half the diameter of the whorl has been removed, and the unusual breadth of all lobes and saddles is thus explained. Upon a specimen whose suture curves had been broadened by such a process was based the species *Goniatites sinuosus*, Hall, taken by HYATT as the type of the genus GEPHYROCERAS.

From the sandy slabs at Naples, N. Y.

GONIATITES.

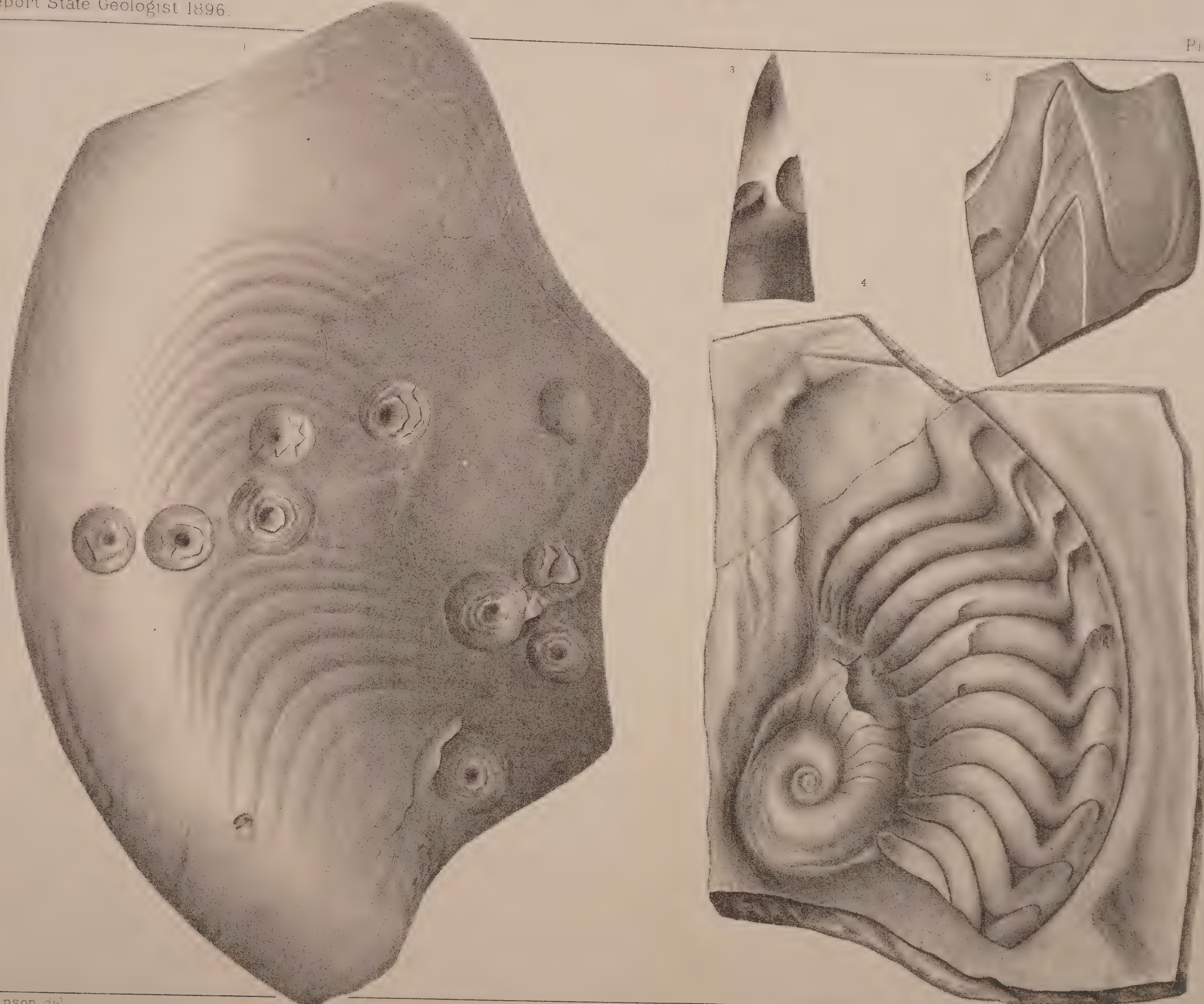


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PLATE IV.

MANTICOCERAS SORORIUM, sp. nov.

Figures 1, 2, 3, 4, 5. These figures illustrate the variation which exists in the ornament of this species during its early phases of growth. The specimens are all gutta-percha squeezes from moulds artificially prepared by a process elsewhere explained, which conserves the surface features with great accuracy. They evince an interesting lack of stability in the development of the ornament. Thus figure 4 has a more primitive aspect than figures 2 and 5, while figure 5 though representing a smaller shell shows its individual progression in its fine ornament, broader whorls and narrow umbilicus. Figure 3 shows the shell (fig. 2) from the rear, illustrates its lateral compression and obscure carination. x 5.

From the calcareous concretionary masses in the shales on Big Sister creek, Erie county.

MANTICOCERAS RHYNCHOSTOMA, sp. nov.

(See Plate V.)

Figures 6, 7, 8, 9. Young shells illustrating the early variations in ornamentation and the early attainment of a smooth surface. In these specimens the protoconch and first volution are not so clearly defined as to render their appearance here quite dependable. x 5.

Figure 10. An older shell, x 3, in which the surface of the final whorl bears only low bands while the umbilicus shows the earlier ornament.

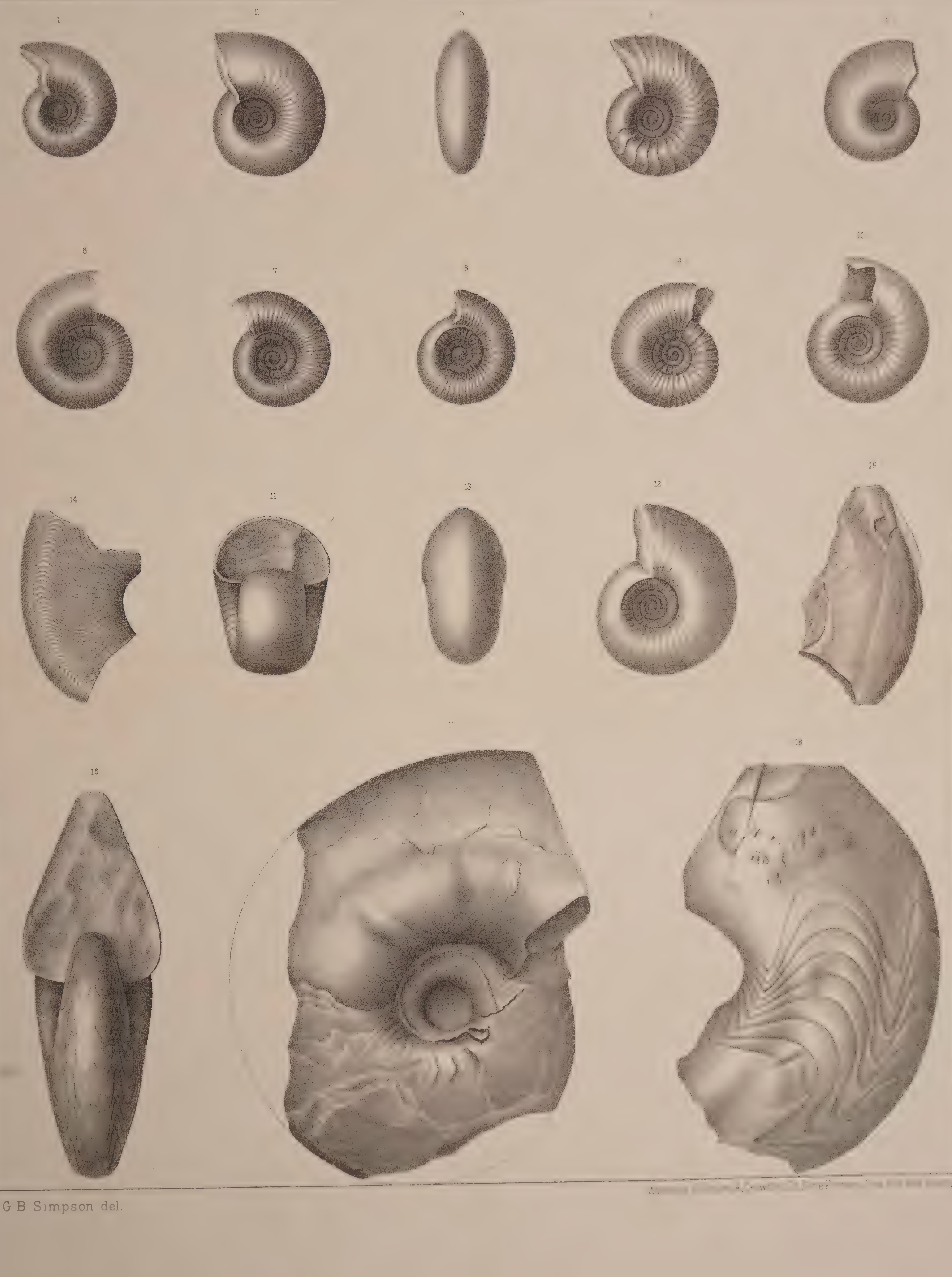
Figures 11 and 12. A still later growth phase with the ornament of the early whorls exposed in the umbilicus. Figure 11 shows the great width of the shell at its aperture. x 3.

All of these early phases are from gutta-percha squeezes.

Figure 13. The ventral side of the fifth whorl, natural size; showing the slight lateral compression at this stage.

The specimens of this species are from Big Sister creek, Erie county.

GONIATITES.



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Manticoceras Pattersoni, Hall (sp.).

(See Plates I and II.)

Figures 14 and 15. Fragments of adult shells, showing the character of the ornament and the strong hyponomic curve. Figure 14 is from a specimen from Rock Stream, Yates county; figure 15, from Naples.

Figure 16. Front view of the ephebic shell represented in figure 10, plate I.

Figure 17. An adult specimen from a calcareous nodule at Naples, which shows very faint nodes near the umbilical margin of the final whorl. They are actually less conspicuous than here represented, but they show the possible derivation of a nodose surface from the phases of ornament through which the shell passes.

Figure 18. A fragment with the *Pattersoni* suture in a progressed condition; from the Chemung formation at Elmira.

PLATE V.

MANTICOCERAS RHYNCHOSTOMA, sp. nov.

(See Plate IV.)

An adult shell preserving the apertural margin. In this remarkable specimen the auriculate expansion of the aperture is situated nearer the umbilical margin than it seems to be in *Mantic. oxy* (see figure 3 on plate I). The body whorl is laterally compressed but not carinate on the venter, as in *Mantic. oxy*, but in this respect is very similar to *Mantic. Pattersoni.*

From Big Sister creek, Erie county.

GONIATITES.

1

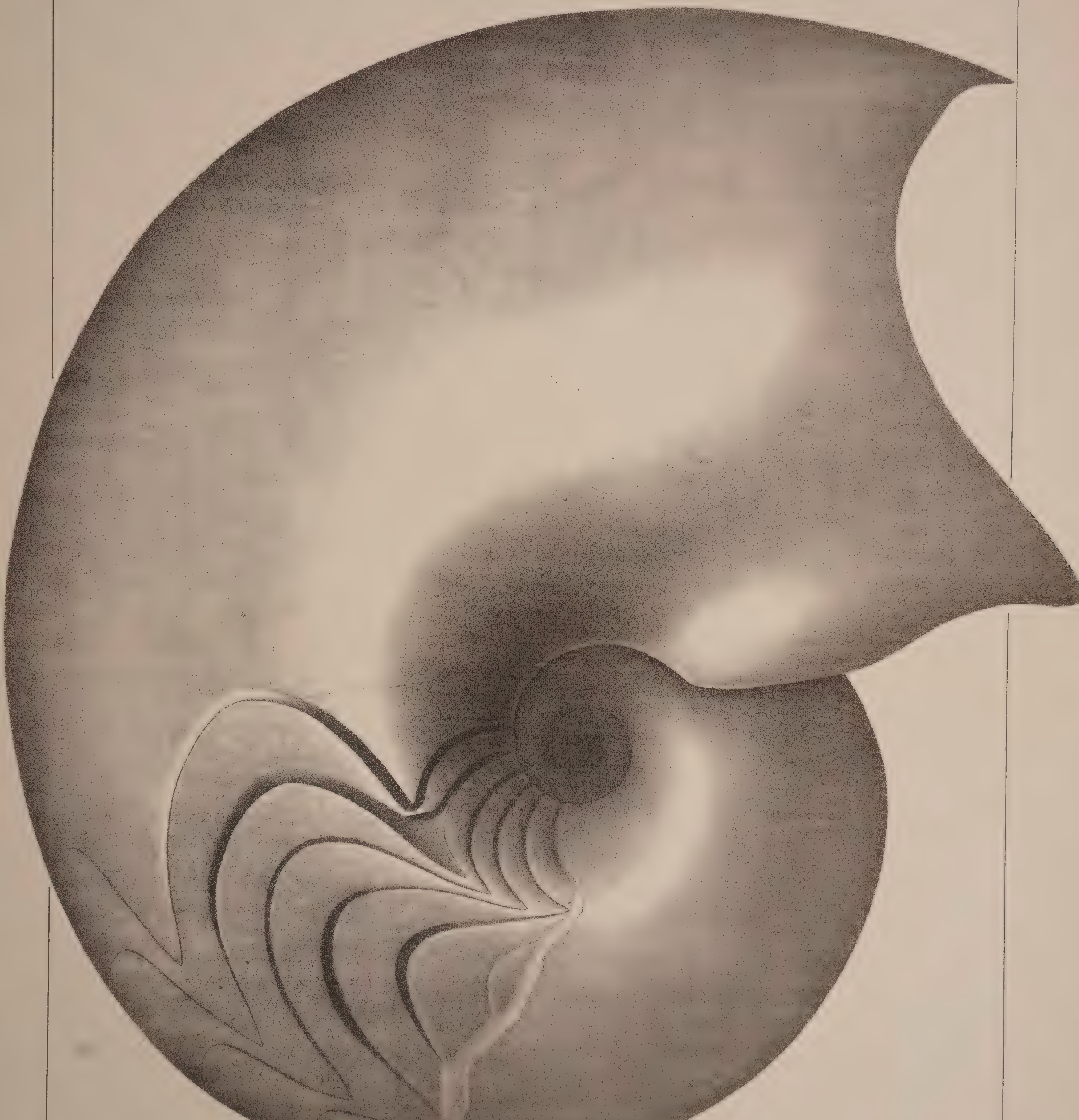

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PLATE VI.

Manticoceras contractum, sp. nov.

Figure 1. A young shell of three volutions. x 3. This is a replacement in sphalerite and retains quite perfectly the character of the surface ornament. It will be observed that the primitive simple varices early become duplicate or fasciculate and are especially prominent on the umbilical slopes. Over the venter is a strong recurvature upon the flattened hyponomic keel.

Figure 2. An older shell, natural size; showing the contracted umbilicus and fine surface striae.

Styliola limestone, Canandaigua lake.

Gephyroceras cataphractum, sp. nov.

Figure 3. Rear view of a young shell showing the impression of a labial ridge upon the surface. x 3.

Figure 4. A young shell of three volutions, showing an almost smooth surface, and the outline of the septum at this growth stage. x 3.

Figures 5 and 6. Shells showing the aspect of the surface. x 3.

Figures 7 and 9. Larger shells showing the rapid expansion of the whorl. x 3.

Figure 8. Front view at four volutions showing the ventral course of the septa and two labial ridges of the interior surface of the shell. With the exception of figures 3 and 8, all specimens are barite replacements.

Java village, Wyoming county.

Manticoceras accelerans, sp. nov.

Figure 10. A specimen showing the very close approximation of all the *intumescens*-sutures. Natural size.

From the soft shales at Naples.

Manticoceras vagans, sp. nov.

Figures 11 and 12. Ventral and lateral views of a fragment showing the *intumescens*-suture and the sharply carinate whorl. Natural size.

From the upper flagstones of the Naples beds, Naples.

MANTICOCERAS FASCICULATUM, sp. nov.

Figures 13 and 14. Distal extremity and lateral view of the protoconch, showing the first septum and the sipho. x 30.

Figure 15. First chamber viewed from the venter, showing first and second septa. x 30.

Figure 16. Protoconch and nepionic shell, showing variation in curve of septa. x 30.

Figure 17. An incrustation in pyrite of the nepionic volution, showing the depth of successive chambers. x 30.

Figures 18 and 19. Shells of three and four volutions, showing the characteristic duplicate or fasciculate ornament and wide umbilication. x 3.

Figure 20. Cast of an early neanic loculus, viewed from the inferior or dorsal side; showing the wrinkles of the inner shell layer on the lateral slopes. x 30.

Figure 21. A shell of mature size showing the early ornament and the smooth, broadened final whorl. x 3.

Figure 22. A somewhat imperfect shell. x 2.

All of the specimens are from the Styliola limestone on Canandaigua lake, and at Middlesex, Yates county.

Figures 13, 14, 15, 16, 17 and 20 are from internal casts or incrustations in pyrite, the others are from barite replacements.

(?) SANDBERGEROCERAS SYNGONUM, sp. nov.

(See Plate VII).

Figure 23. This represents the inner nodose whorls of a very broad backed shell which probably belongs to the species above named. x 3.

From a concretion on Honeoye lake.

MANTICOCERAS NODIFER, Clarke.

Figures 24 and 25. The original specimens of the species. (Coll. National Museum).

Figure 26. An enlargement of the inner whorls showing their nodose character. x 10.

Styliola limestone, Canandaigua lake.

GONIATITES.

Report State Geologist, 1896. Plate 6.

G. B. Simpson del.

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MANTICOCERAS APPRIMATUM, sp. nov.

Figure 27. The inner whorls enlarged to show the character of their ornament. x 3.

Naples beds, Griswold's.

Figures 28 and 29. Ephebic shells from the Styliola limestone, Middlesex

MANTICOCERAS PATTERSONI, var. STYLIOPHILUM.

Figure 30. Adult shell, showing the fine striation of the final whorl.

Naples beds, Naples.

MANTICOCERAS TARDUM, sp. nov.

(See Plate I.)

Figure 31. A shell of four volutions, showing the very wide umbilicus and the simplicity of the ornament. x 3.

Naples beds, Naples.

PLATE VII.

PROBELOCERAS LUTHERI, Clarke.

Figure 1. The primary whorls enlarged; showing the crests upon the venter produced by the concentric varices. x 10.

Figure 2. A shell of two and one-half volutions, broken back to the first septum and showing the length of the body chamber. The ventral ridge is already developed and the crests upon its surface are not resorbed by overlap. x 20.

Figure 3. An older shell, enlarged to the same degree; showing the prominence of the varical crests in their hyponomic recurvatures. x 20.

Figures 4 and 5. Much older shells, of four to four and one-half volutions. They show the character of the suture in this early ephebic condition and the well developed ventral ridge, but they have lost all trace of superficial ornament. x 3.

The foregoing specimens are barite replacements from the calcareous nodules, Honeoye lake.

Figure 6. A small shell showing an early form of the suture. x 3.
Naples beds, Naples.

Figure 7. A mature specimen, natural size. Naples.

Figure 8. The type specimen of *Goniatites Lutheri*, Clarke, Naples.

Figures 9 and 10. Two shells from the shales at Naples, showing the usual aspect of the species, and the latter (fig. 10) exhibiting a fine striation on the final whorl.

BELOCERAS IYNX, sp. nov.

Figures 11, 12 and 15. Specimens, natural size, showing the mature form of the suture.

Figure 13. A young, pyritized shell, showing immature phases of the suture and a fine surface striation. x 3.

Figure 14. Enlargement of a part of another young shell. x 3.

Figure 16. A part of a mature shell which presents the fully developed condition of the suture. x 2.

These specimens are all from the shales at Naples.

GONIATITES.

Report State Geologist. 1896. Plate 7

G B Simpson del. Hallenbeck, Crawford Co. State Prin

GEPHYROCERAS ? (PROBELOCERAS ?) HOLZAPFELI, sp. nov.

Figure 17. A pyritized specimen, showing the character of the sutures. x 2.
Naples shales, Eighteen-mile creek, Erie county.

PROBELOCERAS (?) NAPLESENSE, sp. nov.

Figure 18. A mature shell, showing a portion of the sutures.
From the shales at Naples.

SANDBERGEROCERAS SYNGONUM, sp. nov.

(See Plate VI.)

Figure 19. A portion of the inner whorls, showing the large number of volutions, the wide umbilication and the character of the ornamentation. x 2.
From the shales at Naples.

Figure 20. A specimen from the bituminous slaty shales of the lower black band at Naples. This is the specimen referred to in Bull. No. 16, U. S. Geol. Surv., p. 51, 1885.

PLATE VIII.

GEPHYROCERAS? (PROBELOCERAS?) GENUNDEWA, sp. nov.

Figures 1 and 2. Lateral and ventral views of a young shell, showing the flattened ventral keel. From a sphalerite replacement. x 3.

Figure 3. A somewhat larger shell in a pyritized condition; showing the course of the sutures. x 3.

Styliola limestone, Canandaigua lake.

TORNOCERAS BICOSTATUM, Hall (sp.).

Figures 4, 5, 6, 7 and 8. Young shells showing very wide umbilication and strong, somewhat variable surface ornament. These shells are all very broad on the venter. x 5.

Figure 9. An older shell with less enlargement, showing the almost complete closure of the umbilicus. x 3.

Figures 10 and 11. An older non-umbilicate shell. Figure 11 shows the breadth of the ventral keel and the deep hypnomic curves of the varices. x 3.

Figure 12. Another specimen in which umbilication is complete and low ornamental lines shown. x 3.

These specimens are all from Erie county.

Figure 13. A small specimen from the shales at Naples. x 3.

For illustrations of mature specimens of this species see Palaeon tology of New York vol. v, pt. 2, pl. 72.

TORNOCERAS RHYSUM, sp. nov.

Figure 14. The only specimen observed susceptible of illustration. It shows the undulate surface of the shell and the lateral course of the suture. x 3.

In association with *Mantic. cataphractum* at Java village, Wyoming county.

GONIATITES.

Report State Geologist, 1896.

Plate 8.

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Tornoceras uniangulare, Hall (sp.).

Figure 15. An early phase of the shell enlarged to show its non-umbilicate condition. x 7.

From Honeoye lake.

Figures 16, 17 and 18 are ventral views of ephebic shells of *Torn. uniangulare*, and its vars. *obesum* and *compressum*, in the order named; showing differences in the thickness of the whorl. The specimen of var. *obesum* is from Naples, that of var. *compressum* from the Styliola limestone on Canandaigua lake. x 2.

Cyrtoclymenia neapolitana, Clarke.

Figures 19, 20, 21 and 22. Young shells, showing the strong concave varices of early growth, the otherwise smooth, broad and rounded whorls x 3.

Figures 23, 24 and 25. The ephebic condition of the shell; showing the fine striae of the surface, their strongly developed hyponomic curve, the notable lateral depression, ventral ridge and elongate section of the final whorl. x 3.

From Shurtleff's gully, near Honeoye lake, and various localities in Wyoming county.

PLATE IX.

BACTRITES GRACILIOR, sp. nov.

Figures 1–7. Apical extremities with protoconch. x 25.

Figures 1, 2, 3, 6 and 7, are barite replacements from calcareous concretions at various localities in Livingston and Genesee counties. Figure 1 bears a pretty sharply constricted protoconch, shows the nepionic expansion and contraction of the conch and the surface striation appearing directly after the embryonic period. Slight differences in the size of the protoconch are noteworthy and also in the depth of the constriction where it is attached to the conch (compare fig. 6). The variation in the degree of the nepionic swelling is largely due to difference in point of view. Figures 4 and 5 are from specimens in pyrite, 4 exposing a part of the internal cast and showing septal sutures, and 5 being an internal cast with three septa. These are from soft shales at Attica, N. Y.

Figure 8. A nearly entire shell, natural size. Griswold's, N. Y.

Figures 9 and 10. Lateral and dorsal views of an internal cast, natural size, in which the aperture is preserved entire; figure 10 shows its flaring expansion and low dorsal sinus. Broad oblique undulations are seen over the surface of the living chamber. Honeoye lake.

Figures 11 and 12. Opposite sides of a barite specimen, showing the oblique ridges of the surface and in fig. 12, the fine longitudinal lines. Figure 11 also shows the oblique septum and fig. 12 the position of the sipho. Natural size. Honeoye lake.

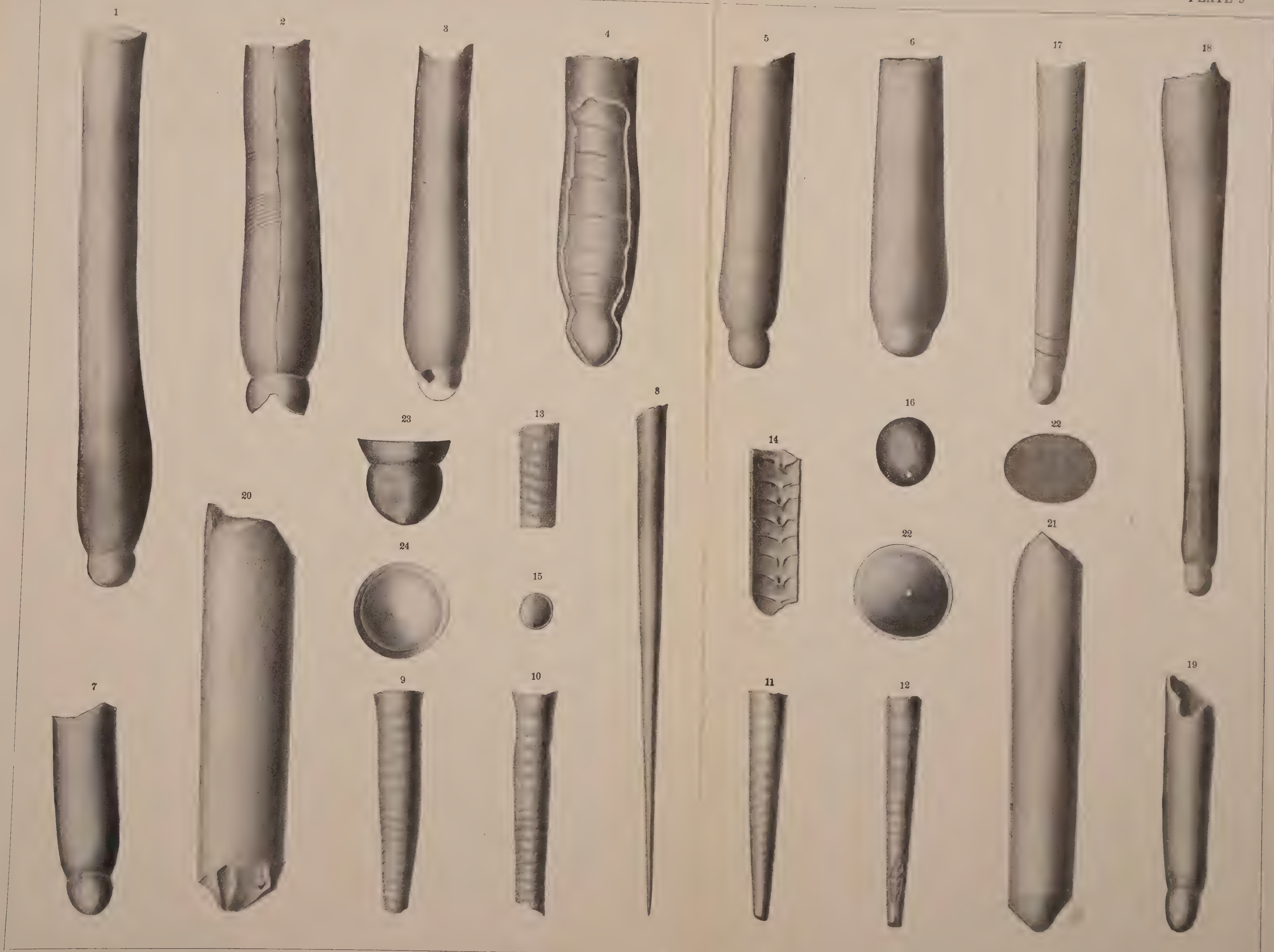
Figure 13. Fragment of another specimen showing the ventral striae crossing the oblique ridges.

Figure 14. Interior of a shell showing the attachment of the siphonal portion of the septa to the internal wall of the conch. x 3.

Figures 15 and 16. Upper and lower sides of septa, the latter x 3.

BACTRITES ACICULUM, Hall (sp.).

Figures 17–19. Slender embryonal tips with small protoconchs, slight nepionic swellings and very gradually expanding shell. These are found in association with the others, and 17 and 18 are internal casts in barite. They evidently appertain to a species distinct from *B. gracilior*, and are hence referred as above. x 25. Honeoye lake.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Figures 20, 21, 22. Lateral and dorsal views, with transverse section, of a large fragment from Naples, N. Y.

Protoconch of Orthoceras (?).

Figures 23–25. Three views of the specimen described by the writer as the protoconch of Orthoceras; here introduced for comparison with the protoconch of Bactrites. x 25.

From the Styliola limestone, Canandaigua lake.

NOTES ON THE EARLY STAGES OF CERTAIN GONIATITES.

By John M. Clarke.

NOTES ON THE EARLY STAGES OF CERTAIN GONIATITES.

By John M. Clarke.

Some Points in the Development of Anarcestes plebeiformis, Hall (sp.).

Goniatites plebeiformis was described by Professor James Hall, in Palaeontology of New York, vol. v, part 2, page 448, 1879, and illustrated on plate cx, figs. 3–9 of that work. It had been previously figured under the name of *Porcellia? rotatoria*, Hall, in the "Illustrations of Devonian Fossils," pl. xvi, figs. 25, 26, 1876, and these figures are also reproduced on plate xvi of the former work. It is a rare and heretofore imperfectly known species, all the specimens having been obtained at a single locality, Cox's Falls, near Cherry Valley, N. Y., in a thin layer of impure limestone belonging to the epoch of the Marcellus shales (lowest middle Devonian). The species is especially interesting because of its primitive characters. It is in all respects a typical Anarcestes, as will be seen upon consulting the figures of whorls and septa as cited.

In its usual mode of retention only the outer whorls of the shells are preserved; hence no illustration has been given of the character of the inner

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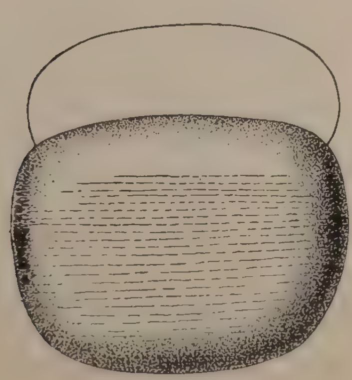

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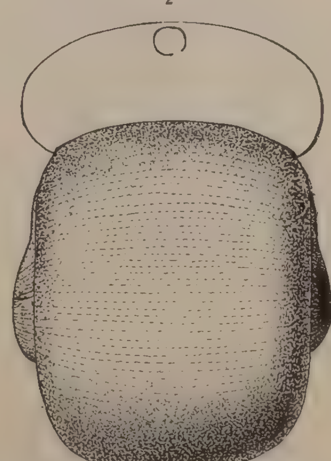


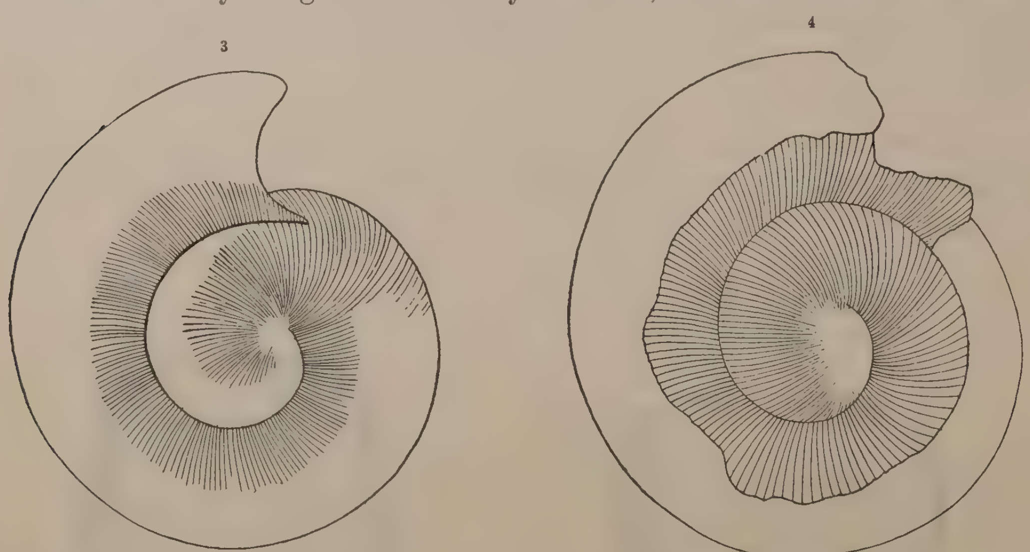
Figures 1, 2. ***Anarcestes plebeiformis.*** **Fig. 1. The distal end of the protoconch, showing its striated surface. x 25. Fig. 2. Front view of the nepionic shell, showing the projecting ends of the protoconch. x 25.**

whorls except in a single instance based on an external mould. The impure limestone is nodular and the outer parts of the shell may be filled with the

limestone matrix while the inner whorls have usually become involved in the clayey portions and are destroyed. Some etchings of the rock have, however, offered solid barite replacements of the inner whorls, and upon these the following observations are based.

Professor HALL called attention to the resemblance of this rare American shell to the *Gon. plebeius*, Barrande from the Bohemian étage G1, an horizon corresponding with that of the former species; its close alliance with *Anarcestes lateseptatus*, Beyr. is very clear. In the mature shell there may be not less than twelve volutions with no tendency on the part of the whorls to become involute. The whorls themselves are exceedingly broad and very shallow, even at the eighth volution the whorl being four times as wide as deep. At the same time the length of the air-chambers is constantly great, having at the eighth volution one-half the width of the whorl, and maintaining very much this relation from the primitive whorls onward.

The Protoconch. The protoconch, though not obtained quite free of envelopment, we find to be of immense size, as witness the figures here given. It is transversely elongate or obtusely fusiform, in direct contact with the



Figures 3, 4. ***Anarcestes plebeiformis.*** **Side views of nepionic shells showing surface striations extending over the protoconch. x 25.**

first volution and carries very distinct transverse ornamental lines almost to its distal surface.

BRANCO has recorded a very large protoconch in the anarcestian species *G. subnautilinus*, var. *vittiger*,* but its size is less than one-half that of this species.

* Palaeontographica, xxvii, pl. vii, fig. I. a, b. c, 1881.

Ornamentation. The fine elevated striæ which appear over a large portion of the protoconch are directly transverse in their course and maintain this character throughout the first and second whorls. Though at first of equal size there is a gradual assumption of disparity until in later whorls the tendency to fasciculation becomes distinctly marked, eventuating in the mature condition, in the formation of node-like bunches near the inner or dorsal margin.

Toward the close of the third volution, the striae begin to show a slight retral or hyponomic curve at the middle of the broad venter, and in the course of the fourth whorl this curve is very distinctly defined, the lines forming a narrow flattened band on the whorl, its width being about one-fourth that of the whorl itself. This band becomes, in later growth, relatively much broader and less distinct, producing in the ephebic condition an obscure flattening of the volution.

Suture. The precise form of the earliest sutures has not been made out, but they could not be much simpler in character than that of all later stages in which this suture line is direct save for a strong ventral lobe. The entire course of the suture at the seventh volution is shown in the annexed figure.

Figure 5. ***Anarcestes plebeiformis.*** The suture at the seventh volution.

The following inferences with regard to the phylogenic status of *Anarcestes plebeiformis* appear to be fully justified:

(*a*) The immense size of the protoconch when compared with that of other ammonoids indicates a closer approach to the stock whence the Goniatitinæ have been derived.

(*b*) The strong ornamentation of the protoconch has been, in other species, regarded as evidence of an acceleration or earlier inheritance. Yet in many later goniatites showing acceleration in various characters not alone is the protoconch devoid of ornament but the entire nepionic shell is also smooth (e. g. *Mantic. Pattersoni*, Hall).

(*c*) The course of the suture is highly primitive throughout the life of the individual.

(*d*) The whorls have, in sectional outline, throughout their existence, the character expressed in only the earliest condition of later goniatites.

(*e*) Not until the growth of the shell is well toward completion is there any apparent gain or loss of umbilication. The ephebic and final whorls show a slight increase in overlap and consequent loss of umbilication.

(*g*) The entire expression of the species is one of extreme simplicity, corresponding well with its early geologic age.

HOLZAPFEL has recently described * an ANARCESTES (*A. Karpinskyi*) from the middle Devonian near Wildungen, which resembles closely *A. lateseptatus* and *A. plebeiformis*, though with less numerous and rather deeper whorls, and he has given a figure of the protoconch with the nepionic conch adhering. Unfortunately the degree of enlargement of the figure is not stated and we can not compare its actual size with that in *A. plebeiformis*. Both protoconch and conch are finely striated, presenting an aspect similar to that of *Agoniatites expansus*, Van., as represented in the following note.

The nepionic conch, however, is stated to be free from the protoconch for nearly a half volution. This mimoceran stage is evidently skipped by the New York species.

The Protoconch of Agoniatites, Meek.

(*Aphyllites*, Mojsisovics.)

The species termed by VANUXEM, *Goniatites expansus*, was redescribed by Professor HALL as *Gon. Vanuxemi*, the change in the specific name arising from the preoccupation of the earlier term. This species abounds and attains great size in certain localities of the Agoniatites limestone of the Marcellus formation; it is also rarely found in the overlying shales of the Hamilton group. The characters of the adult shell have been fully described and finely illustrated in the Palaeontology of New York, vol. v, pt. 1, and vol. vii, Suppl.

The species is one of the typical forms of the genus AGONIATITES, Meek. Recently HOLZAPFEL has included it among the varieties of *Agon. inconstans*, Phillips, thereby expressing the wide geographical distribution of the specific type. The genus includes lenticular, more or less strongly umbilicated shells, characterized by the simplicity of the suture and its slight ontic variations. In early life the suture is purely anarcestian, and at epheby its form has changed mainly by the increase in the prominence of ventro-lateral saddles and the lateral lobes. The protoconch, which has not before been described, is large, its size being great in comparison with goniatites of the later Devonian, but is still less than that of *Anarcestes plebeiformis*. It is rather stoutly ellipsoidal, projecting a little at each side beyond the edge of the first whorl. The surface is finely and sharply striated horizontally from the

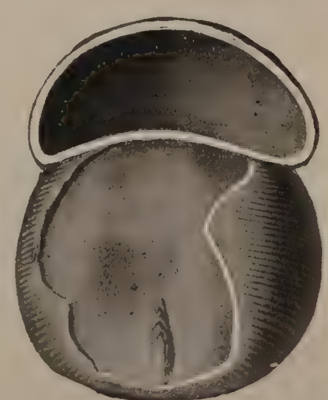
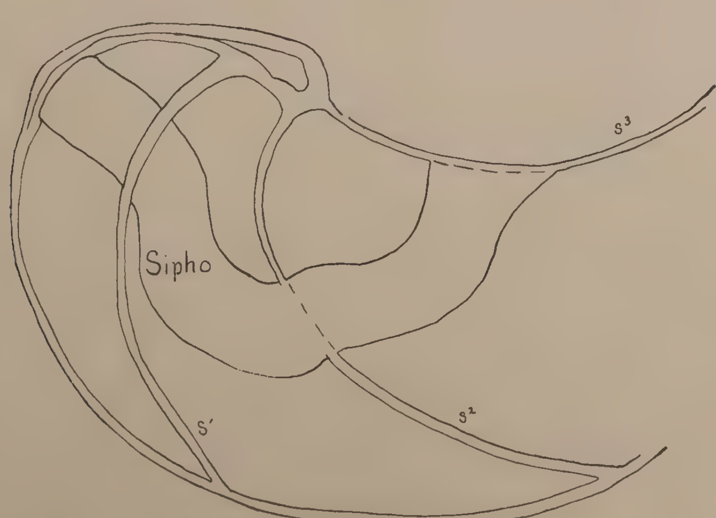


Figure 6. Protoconch of *Agoniatites expansus*, Vanuxem. The striated test is partly broken away, exposing the scar of the siphonal caecum. x 25.

* Die Fauna mit Maeneceras terebratum Sandb., p. 77, pl. 3, figs 15-20, 1895.

distal extremity, these lines continuing without noticeable increase of size for a half revolution of the conch. In later growth these striae develop into more distant, elevated, sinuous lines, eventually, in adolescent stages, becoming distant, low ribs. At maturity such ribs are obsolete or may rarely manifest themselves as a row of nodes near the umbilical margin. There is complete contact between the protoconch and the nepionic whorl. We have noticed above the character of the ANARCESTES protoconch described by HOLZAPFEL; a form similar in all respects to that of *Agon. expansus* (size not included, as the author has given no dimensions for his specimen), save that in the former the protoconch is free from the first half volution. No evidence of any such mimoceran phase has been seen in any of the goniatites examined by me. A portion of the shell of the specimen here figured is so broken as to expose the long and strong impression of the siphonal caecum. This specimen is from the Agoniatites limestone at Manlius, N. Y.

The protoconch of this genus has already been represented by BRANCO in the species, *Gon. evexus*, von Buch. (See Palaeontographica, vol. xxvi, pl. vii, figs. II, a-e, 1881). This has a relatively greater width and is hence more ellipsoidal than in *Gon. expansus*. It is, moreover, of notably less size than that of the latter. That of *Goniatites evexus* has a width of 1 mm., while this dimension in *Gon. expansus* is 1.7 mm. The figures by BRANCO show no surface ornament on the protoconch.



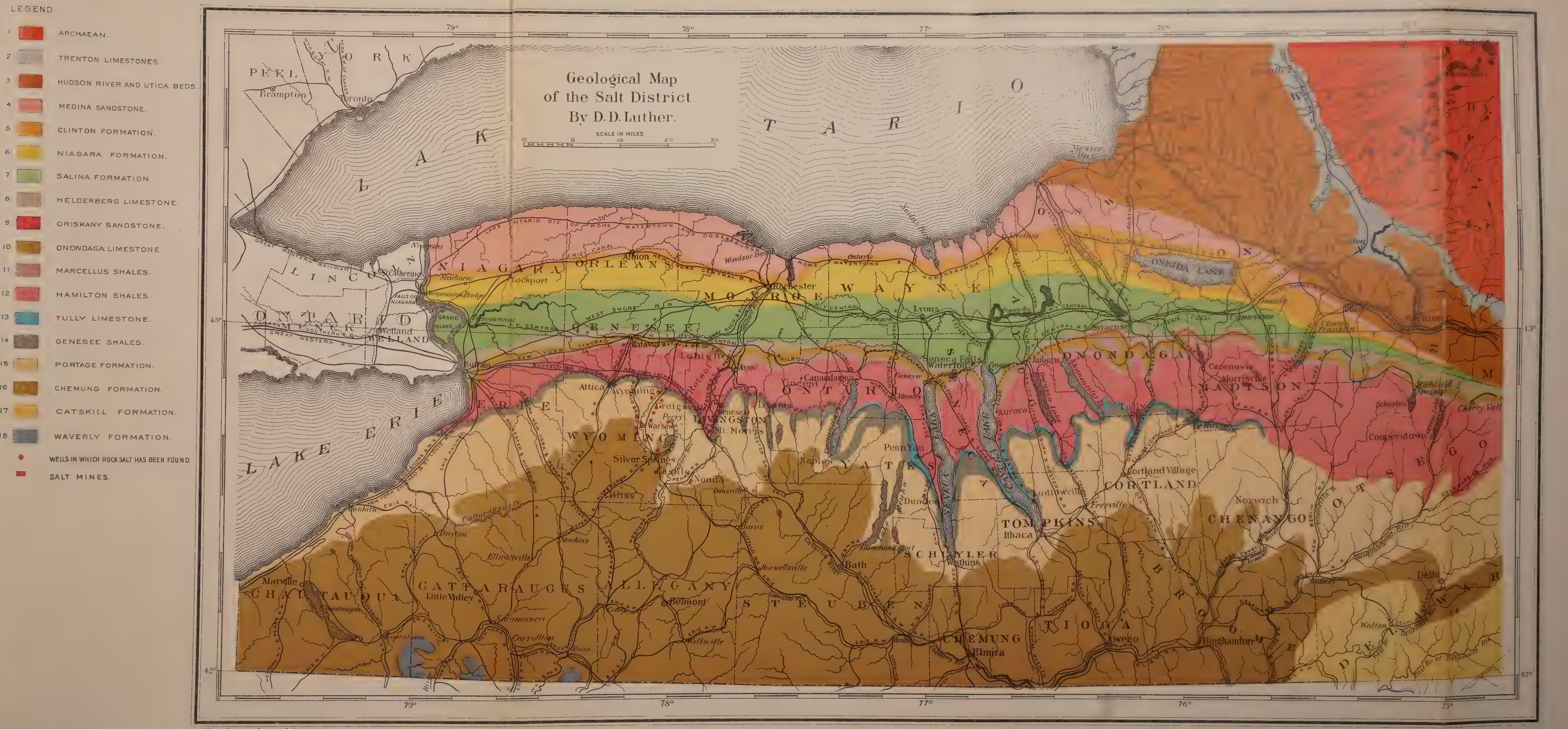
***Nautilus (Eutrephoceras) DeKayi*, Morton. Fox Hills Group, Montana. This is a vertical section through the first three air-chambers and shows the irregular curve of the sipho which has either been almost entirely calcified or filled with a deeply discolored calcite and presents an unbroken course.**

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

The Brine Springs and Salt Wells of the State of New York, and the Geology of the Salt District.

JAMES HALL,
State Geologist.

D. D. LUTHER,
Special Assistant.



WYNKOOP, HALLENBECK, CRAWFORD CO. NEW YORK & ALBANY.

Dr. James Hall, *State Geologist*,

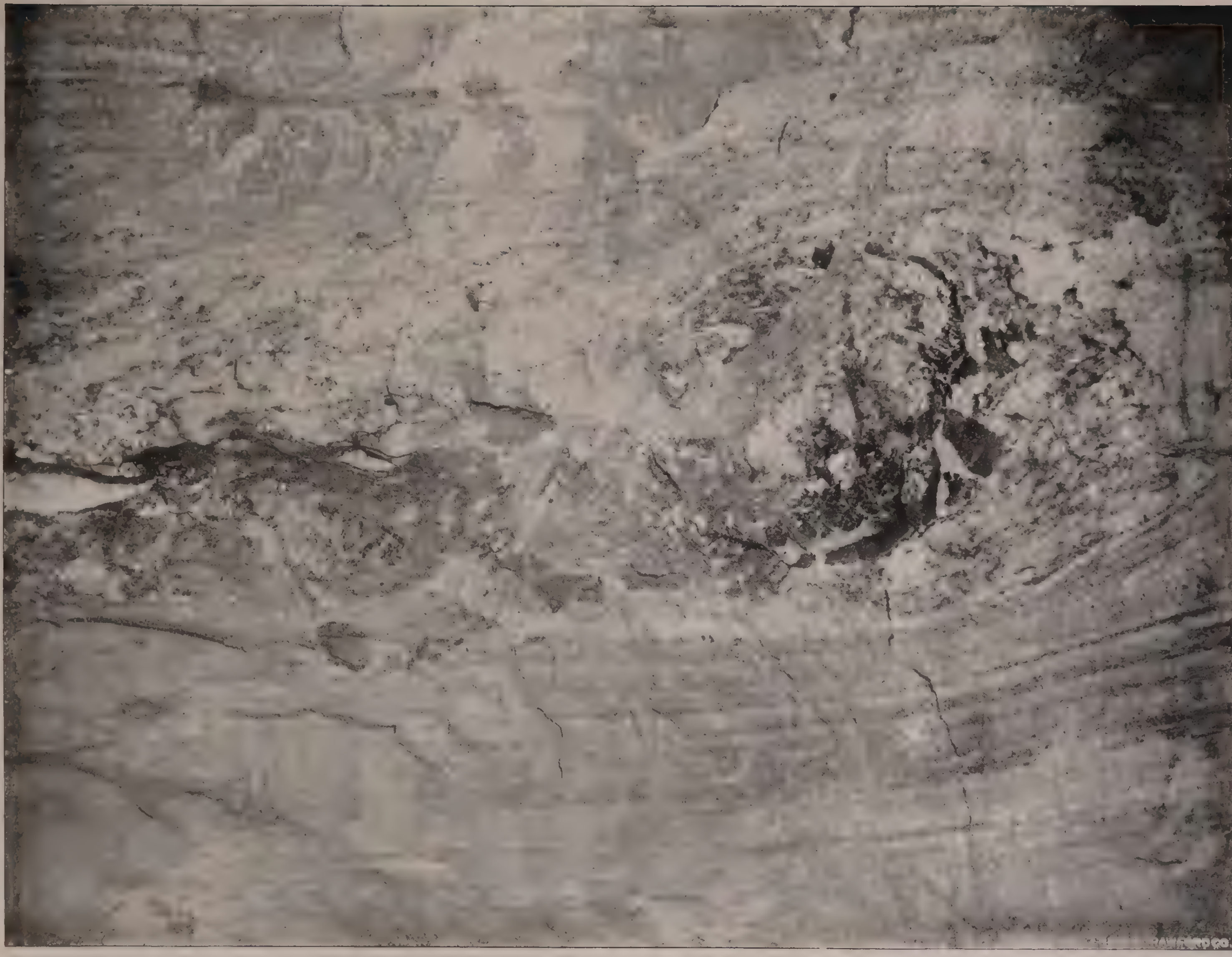
Sir: — Herewith I present my report on the Brine Springs and Salt Wells of New York, and the Geology of the Salt District.

Respectfully yours,

D. D. LUTHER.

February 1, 1897.

PLATE I.



A mass of "mixed salt" in the bed of stratified salt. Livonia salt mine.

The Brine Springs and Salt Wells of the State of New York, and the Geology of the Salt District.

By D. D. LUTHER.

Contents.

Introductory Remarks.

The Chemical and Physical character of Salt, briefly stated. Halite, the salt of commerce, when pure is a binary compound of the two elements chlorine and sodium, and is produced by the combination of one atom of the acidic element chlorine of the weight of 35.4 times that of one atom of hydrogen, with one atom of the basic element sodium weighing twenty-three times that of hydrogen. It is therefore a *chloride of sodium* ($NaCl$) its composition being chlorine 60.7 sodium 39.3 = 100. It contains no water of crystallization.

In its commercial form it usually contains some insoluble matter and more or less of the sulphate of calcium and magnesium, and the chlorides of calcium and magnesium. It belongs to the isometric system of crystallization, the crystals taking the shape of cubes or related forms. Sometimes they are hopper-shaped, or have the form of an inverted quadrangular pyramid consisting of an aggregation of cubes, formed while a nuclear cube was floating and

receiving enlargement at the margin which lay at the surface of the brine. The crystals have a perfect cubic cleavage.

Salt is usually nearly transparent, white or greyish, but is sometimes red and yellow owing to the presence of iron. It crackles or decrepitates when heated and fuses easily, coloring the flame a deep yellow. It is soluble in 2.8 parts of water at 59° F. and in 2.5 parts of boiling water. It is almost insoluble in alcohol. When pure it undergoes no change in the air, but when, as frequently, it contains chloride of magnesium, it becomes deliquescent. Its degree of hardness is 2,—that of common foliated talc being 1, and that of the diamond, 10. It is 2.257 times heavier than distilled water at a temperature of 60° F. and weighs 140.735+ pounds, avoirdupois, per cubic foot.

Mineral or rock salt in the condition in which it is found in the salt mines of New York, weighs 135 pounds per cubic foot, equal to 3000 tons per acre in a layer one foot thick. The standard weight of evaporated salt is fifty-six pounds per bushel, equal to forty-five pounds per cubic foot.

" Most animals appear to have an instinctive relish for its peculiar saline taste, and from its frequent presence in solids and fluids of the animal economy it may be supposed to perform an important part in assimilation and nutrition." (Wood and Bache's United States Dispensatory.)

Nearly all mankind regard the use of salt as an indispensable article of diet, the exceptions being a few cases where milk and raw or roasted flesh constitute the principal food and supply the required amount of saline matter. Its preservative qualities when applied to meats and fish add very greatly to its value and importance and immense quantities are required for use in the arts and manufactures.

The Brines or Salt Springs of New York. Springs of water containing salt in sufficient quantites to be perceptible to the taste are found in nearly all countries; they are especially numerous in the state of New York, mainly in the central and western parts. Many of them were known to the early settlers as "deer licks" and in most cases contained only enough salt to give the water a slightly saline or brackish taste. Others were found in several localities, the brine from which was strong enough to yield salt of good quality and in quantity sufficient to supply the wants of the country and also to become, at a very early date, an article of export.

Springs issuing from the Hudson River formation. In the report on the Geology of the Third District of New York (1842), Mr. L. Vanuxem mentions the following localities where salt springs occur:

The lowest and most easterly is at Saltspringsville in the town of Cherry Valley, Otsego county, near the southwest corner of Montgomery county.

There are indications of salt water at several places in this vicinity. A well twenty feet deep was sunk at one of these and brine of considerable strength obtained. And there is a tradition that before the Revolution the settlers in the vicinity were supplied with salt made here. By using the "five-pail kettles" about forty pounds of salt could be made in a day.

These springs are described (page 62, *op. cit.*) as issuing from slate of the Hudson river formation, which is there of a blackish color, traversed by joints in several directions, and crumbles or falls into fragments on exposure to the air or moisture.

Springs of the Medina sandstone. In Oswego county, one spring is mentioned as situated in the town of Hastings "at an old beaver dam," another as existing in the town of Palermo (page 74).

Others have been found in several localities in the town of Hannibal and salt has been made from a brine in the northwest corner of this town. The brine from the others was too weak for profitable production.

At Sterling center in Cayuga county, a brine spring rises near the creek from a fissure in the sandstone, another was found "near McFarlan's Mill," and another near Little Sodus bay. All of these springs issue from the rocks of the Medina epoch.

In the final report on the Geology of the Fourth District of New York (1843), which included all the counties west of the west line of Cayuga county, Professor Hall mentions fifteen localities where brine springs issue from the Medina sandstones and marls.

In Wayne county one or two springs near the Wolcott furnace were worked in 1815 and produced a reddish salt. They have long been abandoned and are filled with fresh water.

Another from which salt was manufactured in 1831–1832, was near a small creek that empties into Sodus bay. All three springs issued from red Medina sandstone.

In Monroe county, salt was made from brine springs in the town of Webster, in Penfield near the head of Irondequoit bay; and in the town of Clarkson three springs were mentioned by Professor Hall as existing on the banks of Salmon creek and another six miles further north, in what is now the town of Union. Weak brine springs were also found in the town of Parma and in Greece.

All of these springs issue from the Medina sandstones, exept the one in Penfield, which, according to Professor Hall, is from Medina marl.

In Orleans county, town of Kendall, salt was formerly manufactured from the brine of a spring on lot 137, and other salt springs occur in the town. Near Holly in the town of Murray, there are several salt springs and limited quantities of salt were made previous to the opening of the Erie canal. Near West Carlton, while digging a well for fresh water, brine was found that yielded a pint of salt to two gallons of water.

Springs of salt water were found on Johnson's creek in the town of Yates, and near Fairhaven in the town of Gaines.

Salt works were erected in 1805, at a spring north of Medina in the township of Ridgeway, by the Holland Land Company, and opened for the use of settlers. Considerable quantities of salt were made here, and roads were built for the especial purpose of connecting the works with the "Old Buffalo road" on the south, and the "Oak Orchard road" at the north.

In Niagara county, salt was formerly made from the brine of a small spring in the town of Somerset, near the mouth of Fish creek. Other springs of brine too weak to be of commercial value are found issuing from the banks or beds of Eighteen-mile creek, Johnson's creek and Golden Hill creek.

These brine springs issue from red sandstones and shales directly, or through the thin coating of soil spread over them; and these sandstones and shales belong to the upper part of the Medina group. They form the surface rock over a narrow belt of country varying in width from one mile in Wayne county to about eleven miles in Orleans county, and lie adjacent to lake Ontario from Oswego county to the Niagara river. They are the most ancient rocks exposed in the state of New York west and south of the eastern end of lake Ontario.

The south line of the Medina outcrops extends in a generally eastern direction from near the northeast corner of Wayne county across Cayuga and Oswego counties, thence in a southeasterly course to Saltspringsville in Otsego county.

The outcrops of this formation in the territory mentioned, are also the lowest in elevation above the sea, the top of the formation at Oswego Falls beings approximately 340 feet A. T., 93 feet above the level of lake Ontario. Its highest exposure is in Orleans county, where the most elevated outcrop is about 550 feet A. T. and 300 feet above the lake.

Springs of the Clinton, Niagara and Salina groups. No brine springs of any consequence are known to exist in the narrow strip of country lying

next south of the line of the Medina group, over which the shales and limestones of the Clinton and Niagara groups are the surface rocks, but in the belt five to ten miles wide next south of these dark rocks, the lighter colored red, green and grey shales that constitue the lower division of the Salina group, and are collectively known as the "Red Shales," are the surface rocks, and from them issue the weak brine springs at Verona Centre, in the western part of the town of Verona, Oneida county, and also at Canastota, Madison county, where many years ago an unsuccessful effort to obtain stronger brine was made and a well was sunk to a depth of 196 feet.

Brine springs were discovered in this horizon at an early date in the town of Montezuma in Cayuga county, along the banks of the Seneca river, and salt was manufactured here from about 1798 to 1840. These salt works were second in importance in the state and at one period, about 1820 to 1825, produced 15,000 to 20,000 bushels annually. The springs were owned by the state and about 1840 a deep boring was sunk, penetrating 300 feet of red shale, in search of stronger brine, but the works have been abandoned since about that time.

In the town of Cato, Cayuga county, salt springs occur along the Seneca river.

In Wayne county, salt was manufactured about 1815 or 1820, from the brine of a large spring on lot 54, in the town of Savannah, and also in the town of Galen, two miles east of Clyde. Near Clyde, a well bored to the depth of 400 feet produced a small quantity of quite strong brine.

In Genesee county near the center of the town of Oakfield, formerly Elba, are springs of brine from which salt was made at an early day, and these also issue from rocks of the Salina group.

Salt Springs from other Formations. Weak brine issues from the ground in several places in the town of Bethany, Genesee county, from soft shales of the Hamilton group.

A spring of salt water mentioned in the Report on the Fourth District as formerly existing in the town of York, Livingston county, was from nearly the same geologic horizon.

One on Seneca lake, at Big Stream point, in the town of Starkey and one near Watkins, issue from Portage shales.

Weak brine springs or "deer licks" rise along the valley of Halfway brook in the town of Barker, Broome county for several miles, and it is said that a small quantity of salt was made by the Indians and early settlers.

A boring 400 feet deep through olive and bluish shales alternating with sandstone, was made in 1827 to 1838 at one of the strongest springs. The quantity and strength of the brine was found to increase to some extent, but not sufficiently to make it of commercial value.

In the town of Connewango, Cattaraugus county, several weak brine springs have been observed, and near one a shaft was sunk in which brine was found that yielded "about a teaspoonful of salt to a pail of water."

An unimportant brine spring is mentioned by Dr. L. H. Beck as having been found four miles northwest from Delhi, Delaware county, at an elevation of 1384 feet A. T. and another in the same county, three and one-half miles from Colchester.

Doubtless there were many other springs that produced brine sufficiently strong to yield salt, when the need was greater than the labor required to evaporate the water. Located as they were within comparatively easy distances of all parts of the central and western portions of the state, these brine springs were of the greatest importance to the pioneer settlers, and the benefit derived from them could hardly be estimated in money. But when good wagon roads and railways, and especially the system of canals, had reduced the cost of transportation to the low figure that has prevailed for the last fifty or more years, all but one of these reservoirs of brine have fallen into disuse, have become neglected and overgrown, or in many cases dried up and forgotten.

The sole exception is in the Salt Springs Reservation at Syracuse, where the strength of the brine is very much greater than at any of the others and the supply inexhaustible.

The Salt Springs at Syracuse, History and Geology. So much has been written in regard to this subterranean reservoir that the following brief historical sketch condensed from the reports of the superintendents and from the writings of Dr. L. H. Beck, Mr. Vanuxem, Hon. George Geddes, Dr. F. E. Englehardt and others, will suffice for the present purpose.

In the journal of Father Lallemont, a French missionary from Canada who visited that region in 1645–6, a salt spring is mentioned as issuing from the banks of Onondaga lake. This is the earliest historical record pertaining to the famous Onondaga Salt Springs. Another missionary, Father Le Moyne, states that in 1654 he visited a spring here that the Indians declared "was fouled by an evil spirit," from which it has been incautiously inferred that they did not use salt, and had no knowledge of it. Le Moyne made a small quantity of salt from the water and carried it to Quebec.

Other missionaries make mention of the salt springs, and before the English took possession of the country, the Indians had learned to manufacture salt in considerable quantities which they carried to the French settlements at the north and to Albany. They excavated a large hole in the marshy ground on the eastern side of the swamp at the head of Onondaga lake, and this was always full to the level of the ground with salt water that came up from the bottom.

This spring was in the rear of the old Salina pump-house, in what is now the first ward of the city of Syracuse.

In 1789, Asa Danforth and Comfort Tyler, immigrants to Onondaga county, from Massachusetts, made thirteen bushels of salt in twelve hours, using a kettle suspended from a pole supported by two crotched sticks.

This was the beginning of the manufacture of salt by the white settlers.

The next year the business was greatly increased and a settlement of salt makers was made on the bluff above the spring.

In 1790, pumps superseded the use of pails for taking the brine from the spring, and in 1793 the first caldron kettle set in an arch was brought into use.

In 1798, a new well thirty feet deep was dug a little northwest of the first one, and a building the first built for this purpose, large enough to contain eight arches, in each of which four kettles were set, was erected by the Federal Company.

In 1793, the manufacture was begun at Geddes on the west side of the swamp, and also at Liverpool on the north side of the lake. The first wells on the southern border of the swamp, known as the Syracuse wells, were sunk in 1830. Brine was raised from the wells by horse power in 1805, and soon after by water power derived from several small streams in the vicinity. The first works for the manufacture of salt by solar evaporation were constructed in 1841.

In 1797, a tract of land surrounding the head of Onondaga lake and containing 15,000 acres was laid out and set apart by the state for the location of salt works. It was called the Onondaga Salt Springs Reservation. All but about 700 acres has since been sold.

In 1826, the state acquired by purchase extensive pump works driven by power supplied by waste water from the Erie canal, and assumed control of the brine, supplying all manufacturers with any desired quantity for a stated sum for each bushel of salt made.

Since 1797, when the state took possession of the reservation and began leasing lots to makers of salt, an accurate record has been kept of all matters pertaining to the production of salt at this locality.

The annual reports of the superintendents show that in 1797, 25,454 bushels were manufactured. The production reached 100,000 bushels in 1804 and first exceeded 1,000,000 bushels in 1828. The largest amount in a single year was in 1862 when 9,053,874 bushels were made, 2,000,000 bushels being solar or coarse, and the remainder fine salt.

Since 1882, when 3,032,447 bushels of course and 5,307,773 bushels of fine salt were made, the production especially of fine salt has declined. In 1895, it was 733,854 bushels of fine and 2,332,052 bushels of coarse; total 3,065,906 bushels.

The whole product from 1797 to 1896 was 365,434,887 bushels of fifty-six pounds each.

Previous to 1846, the amount charged the manufacturers by the state was variable, and figures to show the revenue derived are not at hand.

Since 1846 the uniform charge has been one cent per bushel and the net profit to the state from that date to 1886 was $668,200. Since 1886 there has been a small deficit each year.

Until about 1825, the brine was pumped from wells about thirty feet deep and eight feet in diameter, located along the eastern border of the marsh at the head of the lake, in the vicinity of the original spring. Later they were sunk nearer the center of the marsh and it was found that clay, sand and gravel were encountered to the depth of nearly 400 feet before solid rock was reached and that as the depth increased in the drift material, the brine had greater strength. Neither brine nor salt was found in the rock that forms the floor of the basin.

In the shallow wells first used it was found that by constant pumping the brine lost a small proportion of salt, but the deeper ones were not so affected. And although more than 10,250,000 tons of salt, enough to cover an area a mile square, which is approximately that of the marsh, to the depth of sixteen feet and three inches, have been taken from the waters of this reservoir, the average strength of the brine is not diminished but rather increased.

In his report for 1890 as superintendent of these springs, Dr. Englehardt says the average strength of the brine from all of the wells, fifty in number, pumped during that year was 70.49° salometer test (100° being full saturation; 100 pounds of brine of 70° strength contains

seventeen and one-half pounds of salt, equal to one bushel (56 lbs.) in thirty-five gallons).

It became evident at an early stage of the development of the manufacture of salt here, that the sands and gravels of the marsh were not the original source of the saline matter contained in its waters, and some effort was made to find it. It had been considered a probability that the red shales exposed along the south-eastern end of the marsh contained rock salt in small grains or crystals disseminated through the mass or in layers. Hence in 1839, a well was sunk by the state to the depth of 600 feet, into the red shales near the Salina pump house, and in 1867 the Onondaga Salt Company drilled a well near the Liverpool pump house to the depth of 715 feet. These two wells were begun near the top of the red shales and passed through them and 100 to 200 feet below, but no salt was found and but a limited quantity of brine.

There the matter rested until after the great bed of rock salt that is beyond doubt the real source of salt in the Onondaga Salt Springs and a majority of the others that have been mentioned, was accidentally discovered in the Oatka valley at a point near its western limit and almost a hundred miles west from the Onondaga Springs.

SALT WELLS.

Their History and Distribution. Rock salt was first discovered in the state of New York in 1865, in a deep boring made on land owned by Eli Rice at the village of Vincent (formerly Muttonville) in the north-east corner of the town of Bristol, Ontario county, for a local company in search of oil.

The geologic horizon of the mouth of this well is about sixty feet below the top of the Hamilton shales. The only record of the rock section is that given from memory by the late Youngs W. Smith, who was one of the managers of the enterprise, to Mr. I. P. Bishop and published by him in the Report of the N. Y. State Geologist for 1885, as follows: Shale about 550 feet, limestone about 450 feet. Shale and salt more than 300 feet with rock salt at the bottom.

In 1882 a well was sunk for the Ontario Improvement Company, on lands of P. P. Bliss, one-fourth mile north of the above mentioned well, and this started in the same geologic horizon. No record of this well can be obtained, but Mr. Bliss states that a bed of clear rock salt 14 feet thick was reached somewhere

between 1100 and 1300 feet from the surface, which fact strengthens the claim in regard to the earlier well.

The owners of the first well failed to realize the importance of the discovery of the rock salt, and the discovery was not generally known, or at least believed, until after the bed had been reached in many other places.

In 1877, the Vacuum Oil Company of Rochester, began the drilling of a well for oil at the mouth of a small ravine on the west side of the valley of Oatka creek, in the town of Middlebury, Wyoming county, about one mile south of the village of Wyoming.

The first rock, reached at the depth of forty feet, was the soft blue Cashaqua shale of the Portage group. The suceeding 593 feet was through soft bluish or black shales, except ten feet of limestone at 300 to 310 feet below the surface. At 673 feet the top of the Corniferous limestone was reached and 597 feet below, 1270 feet from the surface, the drill entered a stratum of rock salt that proved to be seventy feet thick. After penetrating the salt bed, the drilling was continued through 115 feet of red shale of the same character as that exposed in the vicinity of the Onondaga Salt Springs and there ceased.

The discovery was made public at once but it was nearly three years later, in March 1881, that works of a capacity of forty barrels per day were completed and the first salt was made from brine taken from direct contact with the salt bed by artificial means.

This well is known as the Pioneer well.

In the spring of 1879, crystals of salt were found in porous shale at the depth of 610 feet in a well drilled at Le Roy, about twelve miles north of the Pioneer well.

In October 1881, a bed of salt and shale 111 feet thick, of which eighty feet was rock salt, was reached at the depth of 1520 feet in a well near the station of the Rochester and Pittsburg railroad in the village of Warsaw, five miles south of the Pioneer well.

In 1885, the salt deposit was reached in a well at Rock Glen, eight miles south of the Pioneer well, at the depth of 2015 feet, at about the same time, at Silver Springs, two miles further south, at 2224 feet; at Gainesville creek at 2450 feet and at Bliss at 2956 feet below the surface.

All of these wells except the last three are in the Oatka valley, which extends about twenty miles toward the south and a little west from Le Roy. The other three mentioned are nearly in the same line continued about ten miles from the south end of the valley.

It is thirty miles in a direct line from the Le Roy wells on the north to the one at Bliss at the south, and many other wells besides those specified have penetrated the salt beds between these points at such frequent intervals as to prove beyond question that it is continuous the whole distance.

Although the salt bed is so well developed beneath the valley of Oatka creek, it does not appear to extend very much west of it.

In a well sunk in 1887 at Batavia, ten miles west of Le Roy, the record of which was published by Prof. Charles S. Prosser, it is stated that a sample brought up from the depth of 600 feet consisted of "somewhat calcareous chips mixed with crystals of rock salt" and fifteen feet of rock salt were reported as occurring between 600 and 650 feet below the surface.

In the record published by Mr. Bishop, of a well sunk at Attica, ten miles west and a little north of the Pioneer well, the Corniferous limestone is reported, on the authority of one of the drillers, as having been reached at 575 feet and from samples preserved by Prof. T. B. Lovell, brine at 1135 to 1160 feet, "some salt in rock" at 1490 feet and crystals of salt at 1500 feet.

The geologic horizon of the rock salt bed as found in the Oatka valley and at Batavia was reached in the Attica well at between 1100 and 1200 feet, and it is probable that the soft blue gypseous rock in which brine was found at 1135 to 1160 feet occupied that place. The bottom of the Salina shales was reached at, approximately, 1300 feet. Were this record correct, this salt would have come from the Medina sandstones.

In 1890, a well was drilled on lands leased from Mr. O. L. Tozier, of Wyoming county, situated one and one-half miles northeast from Sheldon Center, by parties understood to be in the employ of the Standard Oil Company. The record of the drilling has not been obtained, but Mr. Tozier states that at 1735 feet the drill entered a layer of pure salt seventy-eight feet thick, and that the drilling ceased at about 100 feet below the bottom of the salt and the well was abandoned.

This well is twelve miles directly west from Warsaw. The geologic horizon of the mouth of the well is the upper part of the Portage group, not far below the heavy sandstones, and 1735 feet is about the depth at which the salt layer might be expected to occur.

In a well at East Aurora, Erie county, twelve miles west of the Sheldon well, a stratum seventy feet thick that yielded strong brine was reached at 1465 feet, but it is stated that no rock salt was found.

A well was sunk at Gardenville, seven miles from Buffalo, entirely through the Salina formation, but no rock salt was found.

Strong brine was found in a well at Eden valley, 35 miles west and a little south from Warsaw, at 1025 feet below the surface, and at Gowanda, in the valley of Cattaraugus creek, 45 miles south-west from Warsaw, at the depth of 1700 feet.

The salt bed was first reached in the Genesee valley in 1883, in a well located near the shaft of the Retsof Salt Mine, ten miles directly east from the Pioneer well at Wyoming.

In the ensuing five years following this discovery wells were sunk to the salt at fourteen or fifteen different localities in the Genesee valley or the valleys opening into it.

The most northerly of these was at Teasel Hollow in the town of Caledonia, three miles southwest from the village of Caledonia. The salt bed was found at the depth of 650 feet. Mr. Bishop's record gives the thickness as twenty-five feet. Another authority, Lieut. Evershed states it to be fifteen feet.

The most southerly wells are at Nunda, near the head of the valley of Cashaqua creek, where the salt bed was reached at 2070 feet, and at the head of the Canaseraga valley near Dansville, where it is sixty feet thick and lies 2140 feet below the top of the well.

Reference has already been made to the fact that in the well put down in 1882 at Muttonville (now Vincent), rock salt was found at a depth of 1300 feet. The horizon of the mouth of this well is sixty feet below the top of the Hamilton Group as exposed in a neighboring ravine.

In 1894, a well was drilled one-half mile north of the center of the south line of the town of West Bloomfield, seven miles directly west from the last mentioned well; in this a layer of rock salt nine feet thick was reached at the depth of 1218 feet. The geologic horizon of the mouth of this well is twenty-five feet below the Encrinal band of the Hamilton group, and the top of the Corniferous limestone was reached at 455 feet.

From this record it appears that the layer of salt found in this well is 763 feet below the top of the Corniferous limestone, while in the Livonia salt shaft, distant about eight miles south-west, the salt bed is 502 feet below that point.

In February, 1884, the top of the salt bed was reached in a well at Naples, near the south end of the Canandaigua lake valley, at the depth of 1590 feet. The first stratum of salt was twenty-five feet thick, then rock for twenty feet and below this another layer of salt was penetrated to the depth of eighteen feet when, owing to an accident, drilling ceased, the bottom of the well being in the salt.

All of the wells mentioned thus far have been referred to on account of their location, or the date of the discovery of rock salt in them.

Besides these, many others have been put down and plants for the manufacture of salt have been erected at Le Roy, Genesee county, by the Le Roy Salt Company; Pavilion, Genesee county, by the Pavilion Salt Company; Pearl Creek, Wyoming county, by the Pearl Creek Salt Company; Wyoming, Wyoming county, by the Globe Salt Company; Middlebury, Wyoming county, by the Pioneer Salt Company; Saltvale, Wyoming county, by the Miller Salt Company and the Crystal Salt Company; Warsaw, Wyoming county, by the Warsaw Salt Company, the Standard Salt Company, the Gouinlock Salt Company, the Hawley Salt Company, the Empire Salt Company and the Bradley Salt Company; Rock Glen, Wyoming county, by the Kerr Salt Company; Silver Springs, Wyoming county, by the Duncan Salt Company; Castile, Wyoming county, by the Castile Salt Company; Perry Wyoming county, by the Perry Salt Company. Also at York, Livingston county, by the York Salt Company; Fowlerville, Livingston county, by the Fowlerville Salt Company; Piffard, Livingston county, by the Genesee Salt Company and the Livingston Salt Company; Cuylerville, Livingston county, by the Leicester Salt Company; Mt. Morris, Livingston county, by the Phoenix Salt Company, the Lackawanna Salt Company and the Royal Salt Company; Lakeville, Livingston county, by the Conesus Lake Salt Company.

The records of nearly all of these wells have been published by Mr. Bishop in the report of the State Geologist for 1885, and by Dr. Englehardt in the reports of the superintendent of the Onondaga Salt Springs for 1884 and 1888.

Five shafts have also been sunk to the salt bed; two at Retsof, Livingston county, by the Retsof Mining Company; one at Greigsville, Livingston county, by the Greigsville Mining Company; one, two and a half miles south of LeRoy, Genesee county, by the Lehigh Mining Company and one at Livonia, Livingston county, by the Livonia Salt Mining Company.

A detailed report with diagrams showing the rocks passed through in sinking these shafts was published by the writer in 1894.*

In 1885, a test well was sunk at Ithaca, to the depth of 3185 feet and a careful record was made under the direction of the geological department of

* Thirteenth Annual Report of the State Geologist for the year 1893, vol. I, Geology, Report on Geology of the Livonia Salt Shaft, pp. 23–130, 1894.

Cornell University by Prof. C. S. Prosser. This well is situated about one and one half miles south of the head of Cayuga Lake, and its mouth is eighteen feet above the level of Cayuga Lake and 396 feet A. T.

The following is the section according to the record published by Professor Prosser:

Portage shales	340	feet.
Genesee slate	100	"
Tully limestone	30	"
Hamilton group	1142	"
Marcellus shale	82	"
Corniferous (Onondaga) limestone	78	"
Oriskany sandstone	13	"
Lower Helderberg limestone	115	"
Shale	344	"
First salt, at 2244 feet	24	"
Shale	6	"
Second salt	54	"
Shale	12	"
Third salt	17	"
Shale	31	"
Fourth salt	21	"
Shale	67	"
Fifth salt	42	"
Shale	24	"
Sixth salt	48	"
Shale	82	"
Seventh salt	42	"
Green shale	308	"
Mottled red and green shale	6	"
Green shale	157	"
	3185	"

In 1886, a well was sunk at Morrisville, Madison county, in which rock-salt was found.

The record as reported by Professor Prosser is as follows:

Altitude of mouth of well 1200 feet A. T. approximately.

Hamilton shales	340	feet
Marcellus	31	"

PLATE II.

The stratified salt at an horizon in the Livonia mine where the proportion of gypsum and shaly matter is greater than usual. The dark spots are small pieces of rock.

Corniferous (Onondaga) limestone	70 feet.
[Oriskany	0 "]
Lower Helderberg	209 "
Hydraulic limestone	325 "
Light grey shale	43 "
Dark red shale	5 "
Green and blue marl	87 "
Green and blue marl, with 30 feet limestone	149 "
Rock salt at 1259 feet	10–12 "
Red and green variegated marl	129 "
Red marl	60 "
Green and blue marl	105 "
Red shale	225 "
Blue shale and limestone, Niagara	59 "
Blue shale	22 "
Blue shales and limestone, Clinton	15 "
	1886 "

From this record it appears that the bed of rock salt found here is located 888 feet below the top of the Cornferous limestone, and the total thickness of the strata considered as belonging to the Salina group is 1140 feet, a remarkable increase over that at the nearest exposures or in other wells in which it was penetrated.

The Morrisville well marks the most easterly point at which rock salt has been found in the state, and the most northerly, east of the Genesee river, with a possible single exception.

In 1891 and 1892 several wells were drilled in search of gas in the vicinity of Seneca Falls, Seneca county, in one of which it is said that rock salt was found. Mr. Frank Wescott, of the firm of Wescott Bros. Company, who were connected with the sinking of these wells, states in a letter dated Jan. 2nd 1893, written in reply to inquiry, that "in our well No. 4, three miles north of this place (Seneca Falls) at the depth of 565 feet we passed through eighteen feet of rock salt."

The mouth of the well is about 400 feet A. T., and its geologic horizon is in the gypseous marls of the Salina group but little above the top of the red shales, not more than 100 to 150 feet above the horizon of the great rock salt bed as found at other localities.

The discovery of rock salt at Wyoming revived the interest in the search for the bed that geologists had asserted must exist in the higher lands south of Syracuse, and in 1881 a well was sunk at Jamesville, seven miles south-east from the head of Onondaga lake.

The mouth of the well is 621 feet A. T. and begins in the water-limestones. The well was sunk 1040 feet, ending in the red shales, but no rock salt was found.

In 1882, a well was put down at Cedarvale, seven and one-half miles ssw. from the reservation. The surface level is 702 feet A. T., the geologic horizon near the top of the Coniferous limestone. The total depth of the well is 1151 feet. The bottom of the well was in red Salina shales. No rock salt was found.

In 1884, two deep wells were put down near the Onondaga Salt Springs in search of the deposit of rock salt that was believed to lie somewhere beneath the reservation. The first of these was drilled at the expense of Thomas Gale, Esq., one of the prominent salt manufacturers of Syracuse, and was located near his solar salt fields on the north side of Onondaga lake about three miles northwest from Syracuse. The mouth of the well is 430 feet A. T.

One hundred and seventeen samples of the rock passed through were submitted to Dr. F. Englehardt, and from them a record of the rock section was made and published in the report of the Superintendent of the Onondaga Salt Springs for 1884. From this record it appears that the drill penetrated—

Red shales of Salina group - - - - -	522	feet.
Limestones and shales of Niagara and Clinton groups -	483	"
Sandstones and shales of Medina group - - -	595	"
Total - - . - -	1600	"

Brine was found in Red shales (Salina) at - -	485	"
Dark grey shales and magnesian limestones (Niagara) -	532	"
Light brown sandstone (Medina) at - - -	1395	"
Light brown sandstone (Medina) at . -	1500	"

These brines were all valueless for the manufacture of salt on account of the excessive amount of the chlorides of calcium and magnesium found in them. No crystals of salt were found.

The other well, known as the State well, was sunk at the expense of the state. It is situated near the southeast end of the lake, and about a mile southeast from the Gale well. Its surface elevation is 365 feet A. T.

The record of this well, also published by Dr. Englehardt, is here condensed as follows:

Clay, sand and gravel	400	feet.
Red shales	178	"
Niagara and Clinton	497	"
Medina	830	"
Bluish black slate and grey sandstone; Hudson river	64	"
	1969	feet.

No brine was found, except a little in the upper shales, nor gypsum except in traces, and no rock salt.

In 1888, the Solvay Process Company, of Syracuse, in its search for an adequate and cheaper supply of salt for its very large manufactory of soda-ash, began the sinking of a well at the south end of the valley of Onondaga creek in the town of Tully, Onondaga county, about seventeen miles south of Syracuse.

This valley has an average width of little more than half a mile. The sides are steep slopes, the adjacent hills rising toward the south end to the height of 500 to 800 feet above the bottom, which has a descent toward the north of twenty to twenty-five feet per mile.

The first well was located near the middle of the valley, at the foot of an immense mass of drift that fills the valley from side to side to the height of nearly 400 feet. The top of this morainic filling is a rolling plain that extends many miles southward through the southern extension of this ancient river channel.

After penetrating 400 feet of drift this well was abandoned, and another begun one-fourth of a mile east, at the mouth of a small ravine.

The surface elevation of the mouth of this well, now known as Well No. 1, Group A, is 901 feet A. T. The geologic horizon is a little above the middle of the Hamilton shales.

The Corniferous limestone was reached at 718 feet, and at 1216 feet the drill entered a bed of rock salt that proved to be 45 feet thick. The total depth of the well was 1261 feet.

In 1889, ten new wells were put down to the salt by the same company, in 1890 ten more, and in 1891 nine more, all on the east side of the valley.

These wells are located at regular distances, the line of derricks extending about a mile and a quarter toward the north from the well first drilled.

In 1895 and in 1896, eleven wells were drilled to the salt bed for the same company, on the west side of the valley near the mouth of the Vesper creek ravine, nearly opposite Well No. 1, Group A, making a total of forty-one wells drilled to the salt bed in this locality by this company.

Forty of these wells are connected by iron pipes with the Tully lakes that are situated on the plain at the top of the drift accumulation before mentioned, and water from the lakes is forced by gravity down the wells to the salt where it becomes fully saturated brine. It then flows out through other pipes, and into a large main that receives the brine from all the wells and conveys it to the works at Syracuse, which are 360 feet lower than the mouth of the lowest well.

The bed of rock salt was found in all of these wells and in Well No. 3 of Group G, it is thirty-eight feet thick, but in the "Cardiff well," which was drilled in 1888, and was the next one put down after the salt was found in Well No. 1, Group A, and situated only two and a half miles north of Well No. 3, Group G, the Corniferous limestone was reached at 244 feet from the surface and the total depth of the well was 840 feet, the last 100 feet being all in the red shales. No rock salt was found.

The Solvay wells must be located therefore, near the edge of the salt bed, and it also seems clear that the bed does not become thinner toward the north and gradually "peter out" as it does west of Seneca lake, but ends abruptly, as though a part of it had been removed.

The surface elevation at the mouths of the wells varies from 905 feet A. T. at well No. 6, Group B, to 722 feet at No. 4, Group F.

The thickness of the clay, sand and gravel passed through before reaching the bed rock was ten feet in well No. 1, Group A, eleven feet in Wells 1 and 2 Group C, and increased toward the middle of the valley, where in Well No. 5, Group E, it was 256 feet and in Well No. 5, Group D, 322 feet.

The geologic horizon of the mouths of the wells is the middle of the Hamilton group, the shales of which are exposed in neighboring ravines and are but thinly covered on the hillsides, where the position of some of the harder, sandy layers is made apparent by low escarpments that show the southward dip of the strata in a striking manner. The Tully limestone is exposed near the top of the hill southwest from the wells where it is about thirty feet thick.

In Well No. 30, which is situated at the bottom of the cascade in the ravine of Vesper brook on the west side of the valley, the Corniferous limestone was reached at 675 feet below the surface. Measurement by Locke level from the mouth of the well to the base of the Tully limestone shows the total thickness of the shales between the Corniferous and Tully limestones to be 1173 feet, of which 125 to 150 feet next above the Corniferous are the Marcellus shales and the remainder constitute the Hamilton group.

In Well No. 3, Group G, the Corniferous limestone was reached at the depth of 405 feet and in Well No. 1, Group A, at 718 feet.

The change from the soft black Marcellus shales to the hard, light blue-grey cherty Corniferous limestones is such a marked character that it cannot escape the notice of the driller, and it is the most reliable datum plane found in the salt wells.

The thickness assigned to the Corniferous limestone in the well records varies from 55 to 117 feet, averaging about eighty feet, which is doubtless approximately correct.

The Oriskany sandstone, is found to be fifteen to twenty feet thick. Of the strata next below the Oriskany sandstone, consisting mainly of hard blue-black limestone, and doubtless some layers of hydraulic limestone though none are mentioned in the record, 125 to 150 feet are designated as Lower Helderberg. That part of the Salina group that occupies a position above the salt bed is about 250 feet thick, consisting of grey magnesian limestones and dark gypseous shales, with a bed of the latter thirty to forty feet thick, in which some thin magnesian limestones are interstratified, occurring superjacent to the bed of salt.

The uneveness of the upper surface of the salt bed is shown by the variation in the different wells of the distance between it and the upper surface of the Corniferous limestone where exposed, which is found to be very regular and even.

In Well No. 1, Group A, this distance is - - - - 498 feet.
In Well No. 2, Group A, this distance is - - - 492 feet.
In Well No. 3, Group A, this distance is - - - - 492 feet.
In Well No. 1, Group B, this distance is - - - 495 feet.
In Well No. 3, Group B, this distance is - - - - 518 feet.
In Well No. 4, Group B, this distance is - - - 514 feet.
In Well No. 5, Group B, this distance is - - - - 520 feet.
In Well No. 6, Group B, this distance is - - - 518 feet.
In Well No. 1, Group C, this distance is - - - - 500 feet.

In Well No. 2, Group C, this distance is - - - 497 feet.
In Well No. 3, Group C, this distance is - - - - 500 feet.
In Well No. 4, Group C, this distance is - - - 507 feet.
In Well No. 1, Group D, this distance is - - - - 544 feet.
In Well No. 2, Group D, this distance is - - - 547 feet.
In Well No. 3, Group D, this distance is - - - - 548 feet.
In Well No. 4, Group D, this distance is - - - 548 feet.
In Well No. 5, Group D, this distance is - - - - 545 feet.
In Well No. 1, Group E, this distance is - - - 553 feet.
In Well No. 2, Group E, this distance is - - - - 550 feet.
In Well No. 3, Group E, this distance is - - - 543 feet.
In Well No. 4, Group E, this distance is - - - - 556 feet.
In Well No. 5, Group E, this distance is - - - 551 feet.
In Well No. 1, Group F, this distance is - - - - 546 feet.
In Well No. 2, Group F, this distance is - - - 537 feet.
In Well No. 3, Group F, this distance is - - - - 540 feet.
In Well No. 4, Group F, this distance is - - - 539 feet.
In Well No. 5, Group F, this distance is - - - - 538 feet.
In Well No. 1, Group G, this distance is - - 531 feet.
In Well No. 3, Group G, this distance is - - - . 530 feet.

In the eleven wells on the west side the least distance between the top of the Corniferous limestone and the salt is 499 feet and the greatest 518 feet.

In Well No. 1, Group A, the top of the salt is 315 feet below sea level. In Well No. 4, Group F, 6800 feet north of Well No. 1, Group A, it is 252 feet below sea level, sixty-three feet higher than the former and showing a southward dip of forty-nine feet per mile between these two points.

In Well No. 30 on the west side about half a mile west from Well No. 1 Group A, the top of salt was reached at 317 feet below sea level, two feet lower than in Well No. 1, Group A.

In the Pioneer Well at Wyoming, which is about eighty miles due west from Well No. 1, Group A, the salt bed is 278 feet below sea level, and in the Livonia salt mine, which is located on a line between Well No. 30 and the Pioneer well, the top of the salt is 277 feet below sea level, showing an average westward dip of only six inches per mile.

In a majority of the wells, drilling ceased when the bottom of the first bed of salt was reached, but in nine the drill passed entirely through it and into the shales below. In Well No. 5, Group B, the bed is fifty four feet

thick. The records of all the east side wells show it to have a fairly uniform thickness of about forty-five feet on that side of the valley.

The bottoms of the wells on the west side are from forty-one to ninety-nine feet below the top of the salt. The actual thickness of the one bed of salt referred to in the records at hand is not stated except in that of Well No. 30, where it is given as ninety feet.

All of the salt taken from this locality thus far has been from the upper bed, which contains, after due allowance is made for all impurities, considerably more than 100,000 tons of pure salt per square acre.

The detailed record of Well No. 2, Group A, shows that beneath the first salt bed a stratum of shale forty feet thick occurs, then a second bed of salt seventy-four feet, shale thirty feet, a third salt bed thirty-six feet, shale thirty feet, then a fourth salt bed sixty feet thick, making a total of 204 feet of salt. Drilling ceased in "magnesian shale" six feet below the bottom of the fourth salt bed and 320 feet below the top of the upper salt bed. This is the lowest horizon reached in the Solvay wells.

In Well No. 1, Group B, the record says a total thickness of 318 feet of salt was penetrated, but does not state the amount of shale included.

A well was sunk to the salt bed near Ludlowville, in the town of Lansing, Tompkins county, in 1891, for the Cayuga Lake Salt Company, of which Mr. R. C. Lamberson is president, and a second well was put down in 1892. Works with a capacity of 800 barrels per day were erected in 1891 for the manufacture of fine salt. The grainer, open pan and vacuum pan processes are used.

The only information in regard to the rock section in these wells that could be obtained is that "it coincides with the section in the Ithaca well except as to depth." The wells are located near the tracks of the Lehigh Valley railroad and close to the shore line on the east side of Cayuga lake, about eight miles north and two miles east from the Ithaca test well.

A vertical wall of rock extends parallel to the lake shore nearly the whole distance from the head to Aurora, and rises sometimes to the height of 100 feet or more. The bluff is back from the water's edge a sufficient distance to allow space for the railroad tracks that wind along between it and the lake. A wide break in the escarpment occurs near the Ludlowville station where the valley of Salmon creek opens into the lake basin. The rocks have been entirely removed for some distance back from the lake and a great accumulatien of delta gravels and drift has taken their place. They are abundantly exposed, however, a little further up the stream, which, near Ludlowville, flows through a rocky ravine and forms a high cascade.

For a distance of about ten miles southward along the lake shore from Aurora, the escarpment is composed of the soft, bluish clayey shales of the Hamilton group, the lines of bedding showing a distinct but rather undulatory southward dip.

In the vicinity of King's Ferry the upper part of the ravines expose the Tully limestone about 15 feet thick and 200 feet above the lake. It gradually approaches the shore and becomes the cap-stone of the escarpment near Lake Ridge. It is continuously exposed southward in the face of the bluff showing several low undulations. In the vicinity of Taughannock the lower layer reaches the level of the lake and is partially submerged. Approaching Ludlowville the limestone rises to the top of the escarpment on the north side of the Salmon creek opening. On the south side of this break in the escarpment it again appears high up on the bluff, descending rapidly toward the south and disappearing beneath the waters of the lake two and half miles from the head.

The extensive anticlinical flexure indicated by the position of the Tully limestone as above set forth is referred to by Professor Hall in the report on the Fourth District and by Mr. Vanuxem in the report on the Third District. Its position and dimensions as it appears on both sides of the lake are more particularly described by Prof. S. G. Williams of Cornell University in the Sixth Annual Report of the State Geologist, page 22.

Professor Williams says that the flexure carries the limestone to the height of 230 feet above the lake at Norton's landing and that on the west side of the lake the limestone is submerged on the north side of the flexure, rising above the water between Trumansburg landing and Taughannock and forming an arch 160 feet high and nearly four and a half miles span, passes beneath the water again about three and a half miles north of the head of the lake.

A fold of this magnitude must affect the strata to a great depth, far below the salt bed.

In the Ithaca test well, the Tully limestone was reached at the depth of 440 feet below the mouth of the well, or 422 feet below the lake level. Adding the height of the arch at Norton's landing, 230 feet, gives an elevation of the strata of 422 feet + 230 feet = 652 feet.

The unusual thickness ascribed to the Hamilton group in the Ithaca well shows its great increase toward the south. Data from which to ascertain the exact difference in the thickness of these shales at Ithaca and at the mouth of Salmon creek are not at hand, but it is probably more than a hundred feet.

The Tully limestone is thirty feet thick at Ithaca and fifteen feet at Ludlowville.

These conditions indicate an elevation of the salt bed, which was reached at 2244 feet below the surface in the Ithaca well, to about 1500 feet below

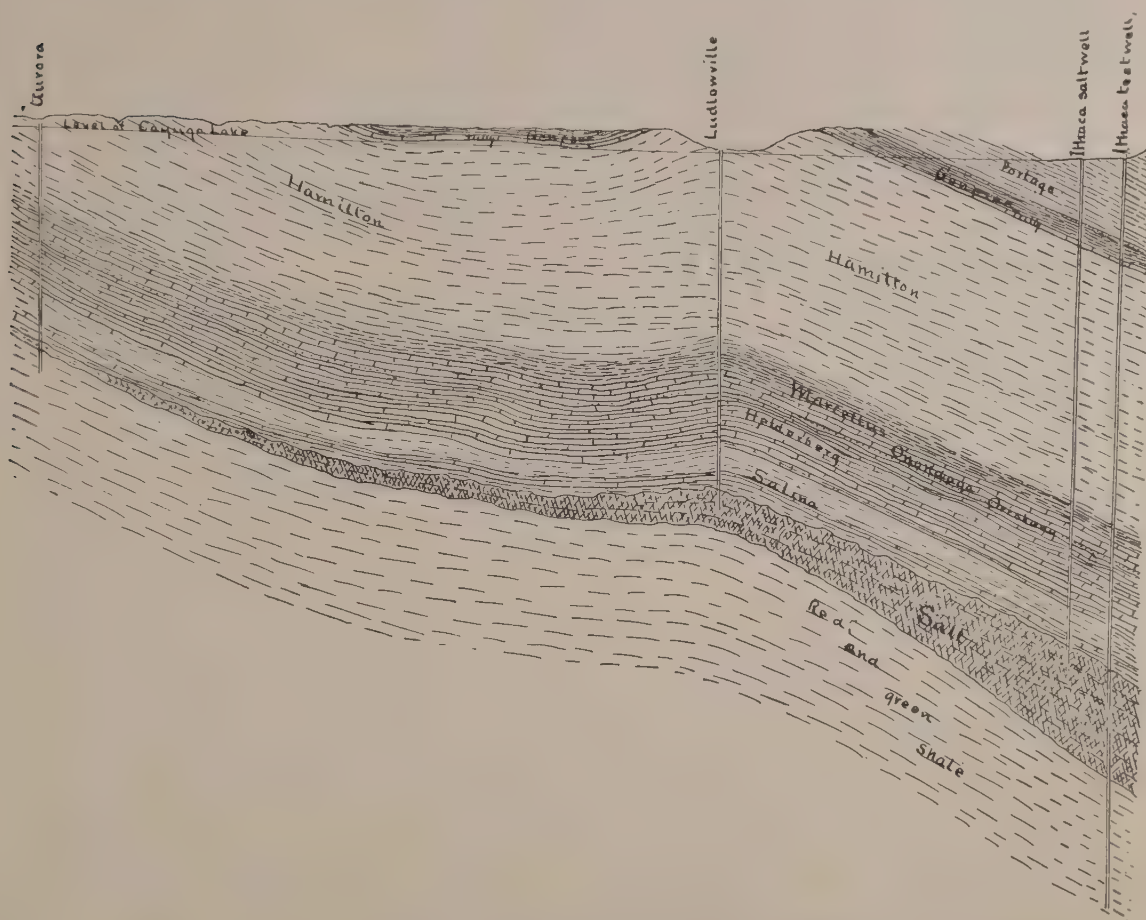


Figure 1. The flexure near the south end of Cayuga lake.

the surface of the lake on the apex of the flexure near the mouth of Salmon creek.

In 1895 the Ithaca Salt Company, Hon. L. H. Humphrey, Pres., had a well drilled to the salt in the city of Ithaca one and one-fourth miles north of the test well before referred to, and immediately began the erection of a plant for the manufacture of fine salt. The plant was completed and a second well put down in 1896. Grainers and open pans are used and the works have a capacity of 800 bbls. per day. The works are located between the tracks of the Delaware, Lackawanna and Western, and the Lehigh Valley railroads, on the low grounds in the north part of the city and near the head of the lake. The surface level at the mouth of the wells is 386 feet.

On account of the proximity of the test well no detailed record of the rock section in these wells was preserved.

From Mr. M. E. Caulkins, secretary of the company, it was learned that the first rock was reached at the depth of 429 feet, and the top of the salt at 2150 feet.

The section coincides in all respects with the record of the test well except as to depth, the difference being about 100 feet.

At the depth of 1685 feet a stratum of quartzite, evidently the Oriskany sandstone, as appears on examination of samples preserved, was encountered and was penetrated with much difficulty, the rock cutting away the edge and corners of the drill very rapidly.

At 1800 feet, a vein of water was opened that filled the well to the top, which is strong evidence that the movement which produced the foldings and undulations in the rock strata also caused fractures and fissures by means of which surface waters penetrated to a great depth.

In 1893, a well was drilled to the salt near Watkins, Schuyler county, for the Glen Salt Company, of which Mr. G. C. Otis is president and Mr. C. L. Paar, secretary, by F. J. Adams of Bradford, Pa.

In 1894, a second and, in 1896, a third well was sunk for the same company. Works having a capacity of 1000 bbls. per day were erected and put in operation in 1894, in which fine table and dairy salt is manufactured by the vacuum pan and grainer processes.

These wells are located at Salt point (formerly Coal point) on the west side of Seneca lake, one mile from the head. The surface elevation is 450 feet A. T., and the geologic horizon is in the shales of the lower part of the Portage group. The dip of the strata is slightly toward the north, apparently about ten feet per mile.

No detailed record was kept of the changes in the character and color of the rocks encountered in the drilling by which the thickness of the different formations passed through can be ascertained, only the distances to the top of the salt and to the bottom in each well having been accurately measured. Mr. Paar states that the top of the salt was reached in Well No. 1, at 1841 feet from the surface; drilling was continued sixty-one feet deeper, all in salt except two feet of shale about thirty feet below the top of the bed, which also occurs in the other wells.

In Well No. 2, the salt bed was penetrated 102 feet.

The bottom of well No. 3 is in salt 1927 feet below the surface.

Mr. Adams states that he drilled through 600 feet of limestone overlying the salt bed, the upper 400 feet being much harder than the lower 200 feet. He also states that the bottom of the salt was not reached in any of the three wells.

About the year 1890, a deep boring was made at Dundee, Yates county, for Mr. George Borden and others, in which it has been reported the salt bed was reached. No information whatever can be obtained from the owners in regard to the rock section in the well.

It is located on the high ridge between Seneca and Keuka lakes, ten miles northwest from the Watkins well, at an altitude of about 100 feet A. T. The geologic horizon of the mouth of the well is in the upper Portage shales and flags, approximately 450 feet higher than that of the Watkins wells.

An allowance of 100 feet for decreased thickness of the Hamilton group would make the probable depth to salt about 2200 feet. No use is made of this well.

No wells have been drilled to the salt in new localities during the last three years, owing to the depression in the business of manufacturing salt, and several of the smaller and less favorably located plants have ceased operations entirely.

GEOLOGY OF THE SALT DISTRICT.

Nearly all the geologic formations from the top of the Hudson river slate to, and including the Chemung group, into which the rock strata found in central and western New York have been divided, have brine springs issuing from them or occupy such positions as to require that they be drilled through in sinking wells to the great rock salt bed.

Named in the order of their positions in the strata, beginning with the highest in which wells that were sunk to the salt bed have had their beginning, these formations have been designated as follows:

Chemung group, Portage group, Genesee slate, Tully limestone, Hamilton group. Marcellus shales, Onondaga limestone, Oriskany sandstone, Lower Helderberg limestone, Salina group, Niagara group, Clinton group Medina sandstones, Hudson river slate.

They are all sufficiently persistent in character and thickness to enable a careful observer, by an examination at one exposure, to identify the same formation at others and to follow the line of its outcrops without much difficulty, but they not only differ from each other more or less in thickness and the character, condition and color of the sediments of which they are com-

posed but they are also individually uneven in thickness and variable in character.

Two or three formations that have strongly marked characteristics, and are important and easily recognized bench marks in the eastern part of the salt district, thin out and entirely disappear before reaching the western counties. Others have their highest development in the central or western part of the state.

The strike or line of surface exposure of any given formation is in its general course on an east and west line and approximately parallel with the southern shore of Lake Ontario, but the uneven elevations of the numerous hills and valleys make it extremely tortuous in detail.

The dip of the strata toward the east or west is hardly appreciable except in the vicinity of an undulation, though the beds are rarely or never, exactly horizontal.

Cross sections of the strata show a general dip toward the south. Over a large part of the district forty feet per mile is considered a fair average of the amount of the dip, but it is very irregular, and varies from 100 feet or more toward the south to almost as much toward the north, revealing the existence of many undulations in the strata, some of which are extensive and important.

Besides the undulations, which are low in proportion to their width, and over which the strata rise and fall in easy, graceful curves, there are many small but sharp anticlinal folds where the layers of rock are fractured at the apex and at the base on both sides.

The sides sometimes have an inclination of 45°, but usually much less.

There are also many dislocations of the strata in overthrust and vertical faults, and fissures and joints that must penetrate to great depths are more or less common in all of the formations.

Hudson river group. The Hudson river group, as developed in the Third District, includes the Frankfort slate, Lorraine shales, and the Pulaski shales of Vanuxem's report. They constitute the upper or third division of the rocks of the Trenton period of lower Silurian time.

No distinct line of separation has as yet been clearly laid down between the base of the Hudson river slate and the Utica slate.

The dark blue and black bituminous and fissile slates of the latter formation pass by almost imperceptible gradations into much lighter colored and more arenaceous beds with which thin layers of grey sandstone frequently are interstratified. No thin limestone, as in the case of the Utica slate,

PLATE III.

A horse in stratified rock-salt. Livonia salt mine.

appears in this state west of the central part of Oswego county. The sandstones are of more frequent occurrence and much heavier in the upper part of the formation, and in many localities are crowded with fossils.

The Hudson river slate and sandstones are the surface rocks of a large area in the northern and eastern part of Oswego county and of Jefferson, Lewis and Oneida counties and crop out along the south side of the Mohawk valley in Herkimer and Montgomery counties.

The upper beds thin out toward the east and dissappear before reaching Salt Springville, and the brine springs, found here and previously mentioned as being the lowest in the strata in the state, issue from the upper part of the softer lower division of the group, which is here in direct contact with the rocks of the overlying Medina formation.

It is exceedingly difficult to determine in a well boring just when the limits of this group are passed, and hence its thickness in this region has been accurately fixed in but few places.

In a deep well at Utica, the thickness of the Utica and Hudson river slates and sandstones aggregated 800 feet. Inone at Fulton, Oswego county, as found by Walcott, 1000 feet; in one at Wolcott, Wayne county, reported by Prosser, 1030 feet, and in the one at Rochester, according to Fairchild, 598 feet.

Oneida conglomerate. Next in the order of superposition there occurs in the eastern part of the district under consideration, a bed of coarse red and white sandstone in which are embedded roundish pink and white quartz pebbles in great numbers. This is the Oneida conglomerate. It is best developed in Oneida county, where it attains a thickness of 100 feet or more. It thins out rapidly toward the east, disappearing under the drift in Herkimer county, to reappear in the Shawangunk mountains where it has received the local name of *Shawangunk grit.* It also thins out, or loses its pebbly character in the western part of Oswego county, whence westward on the shores of lake Ontario the lowest surface rocks belong to the division of the Medina group known as the Medina sandstones.

Medina sandstone. These rocks are not all sandstones but include many beds of shale. Red is the predominating color in both sandstones and shales, but the former are sometimes white, grey, or mottled, and the latter frequently bluish or olive.

Professor Hall recognized the following subdivisions of the Medina sandstone beds: At the base, (1) greenish grey sandstones with no distinct line

of separation from the Oneida conglomerate below, succeeded by (2) beds of argillaceous sandstones and shales, red or mottled red and grey; (3) grey, laminated sandstones called by Eaton the *grey band*, and (4) red shales and shaly sandstones banded and mottled with red and green.

Very few of these beds are of a persistent character entirely across the district, but beds of sandstone that are compact and valuable for building material at one locality, are too soft and shaly for that purpose at others.

As but a part of the group is exposed in the belt over which it is the surface rock, the total thickness of its beds can only be ascertained in the few deep borings that have passed through them.

In his record of the State well at Syracuse, Dr. Englehardt makes the total thickness of the Medina sandstone, 740 feet.

If, as seems probable, the grey sandstones next below are in the horizon of the Oneida conglomerate or Oswego sandstones the thickness of the entire group at this locality would be increased twenty-five to fifty feet.

In the Rochester well, Prof. H. L. Fairchild ascribes a thickness of eighty-three feet to the "Oneida or Oswego," and 1075 feet to the red Medina, making a total of 1158 feet for the entire group.

Nearly all of the numerous brine springs that are found in the counties adjacent to lake Ontario issue from the sandstones, but there is nothing in the character or appearance of these sediments from which the existence of salt crystals at the present or any former time can be inferred. On the contrary, their condition indicates an extensive sandy flat shore, exposed to the influence of strong currents, tidal and otherwise, where evaporation of the sea water could make but small progress.

In the Gale well at Syracuse, brine was found in two of the Medina sandstone layers, while in the State well, but little more than a mile distant, no brine occurred in that formation.

A large number of deep borings have been made into the upper sandstones in search of natural gas, in the vicinity of Seneca Falls, Seneca county, West Bloomfield, Ontario county, Caledonia and Avon, Livingston county, LeRoy and Batavia, Genesee county, the city of Buffalo, and other localities. In some of the wells, a considerable pressure of gas is found in the sandstone beds 100 to 250 feet below the top of the group. In other wells a short distance away, little or no gas is present.

In central New York the exposure of the rocks of the Medina epoch begins near the southeast corner of Herkimer county, on the south side of the Mohawk valley, and extends toward the northwest over a very narrow strip

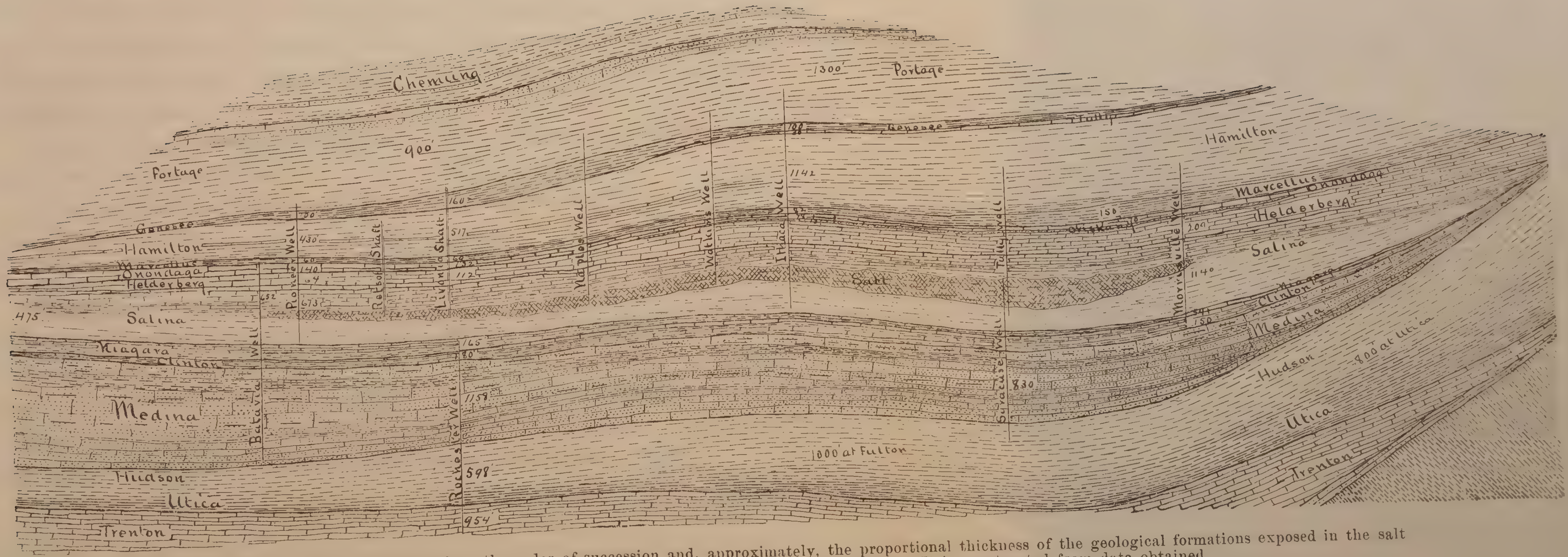


Figure 2. Diagram designed to show the order of succession and, approximately, the proportional thickness of the geological formations exposed in the salt district of New York, and also those penetrated in the deep wells. It is constructed from data obtained from the well records and by measurement of outcrops.

of country that expands in the western part of Oneida county and occupies a considerable area in the southwest part of Lewis county, nearly the whole of Oswego county, and a belt along the shore of lake Ontario that varies in width from one and a half miles in Wayne county, to eleven miles in Orleans and Niagara counties.

Clinton group. This next division in upward succession embraces strata of such a diversified character that it was designated by Vanuxem the "Protean group."

In Mongomery, Herkimer and Oneida counties the Clinton rocks are from 100 to 200 feet thick, and include thick beds of greenish grey and red sandstone, and of green and blue-black shales. The sandstones are sometimes slightly calcareous; two beds of lenticular argillaceous iron ore are interstratified with them.

In the western counties the rocks are less arenaceous, and limestones of considerable thickness occur.

In the gorge of the Genesse river at Rochester, the section is as follows, from below upward:

Green shale, sandy and harder toward the bottom, and containing a bed of iron ore near the top - - - - - - - -	24 feet.
Limestone with shaly partings, and one foot layer of fossiliferous iron ore - - - - - - - - - - - - -	14 feet.
Green clayey shale, in which an irregular layer of fossils known as the "pearly layer" occurs - - - - - - - -	24 feet.
The "upper limestone" composed of alternating thin layers of limestone and shale - - - - - - - - - -	18 feet.
Making the total thickness of the Clinton formation at that locality	80 feet.

On Niagara river, the lower green shale has decreased in thickness to four feet and the second bed of green shale has disappeared, the limestones meeting and becoming one bed, twenty-five feet thick; the whole group having been reduced to two beds which aggregate twenty-nine feet.

The Clinton beds are the surface rocks over a narrow belt beginning at a point in Montgomery county and extending westward on the south side of the Medina sandstones to the western border of the state.

The belt is about eight miles wide in the vicinity of Oneida lake, which lies entirely within it. This is its greatest width. West of Cayuga county it is less than two miles wide.

Owing to the variable character of the Clinton rocks, the limits of the group are not easily recognized in deep borings, and in most of the well records the strata are partly or wholly included under the term "Niagara" with the next overlying group.

Niagara group. This group, so named because it is composed of the strata that appear in the face of the precipice at Niagara Falls, overlying the bed of Clinton limestone that comes down to the water level at the foot of the cataract, has two subdivisions, the Rochester shale at the base, here eighty feet thick, and the Lockport limestone eighty-five feet thick, rising above it to the crest of the fall.

The shale is soft, clayey and slightly calcareous, dark bluish-grey in color, weathering rapidly to a light ashen grey.

When freshly excavated it has a tough texture with little appearance of a slaty structure, but on exposure it soon separates into small angular fragments, and softens into a mass of greyish, marly clay.

Thin layers of impure limestones occur in the middle and upper parts of the beds, composed largely of corals and other fossils. These fossils are also abundant in the shales.

The Lockport limestone is best developed in this state in Niagara, Orleans and Monroe counties. At its base there are a few feet of impure limestone, which was formerly burned for water-lime. Above these layers is a bed of light colored crinoidal limestone, succeeded by a darker mass containing geodes, and this again by thin nodular layers of concretionary limestone, separated by thin partings of carbonaceous shale.

The limestones are very bituminous and are also magnesian and should be known as dolomites. Geodes are abundant at many localties and contain beautiful crystals of calcite, dolomite, gypsum and celestite.

The rocks of this formation are exposed on both sides of the chasm between Niagara Falls and Lewiston, and thence eastward in the great limestone ridge across the county, where it has been largely opened for quarrying at Lockport and vicinity.

The chasm at the upper falls of the Genesee river at Rochester has been excavated in this group, and the limestone is extensively quarried in and about the city. The thickness of the Rochester shale is about the same in the gorge of the Genesee river as at Niagara Falls, but the limestone is slightly thinner. Both shale and limestone gradually become thinner toward the east, the belt of which they are the surface rocks becoming narrower as it extends across Monroe, Wayne and Cayuga counties, and the northern towns

of Onondaga county, where the limestones are very dark and bituminous and less than ten feet thick. The shales are so heavily covered by drift that their thickness is not known.

The limestone appears occasionally in Madson and Oneida counties and in the valley of the Mohawk river, south of the village of Mohawk, Herkimer county. It reappears as a thin layer known as the Coralline limestone, in the Schoharie creek, near the foot of the Helderberg mountains.

The Niagara is a moderately deep sea formation, and no traces of salt have been found in it. The deposition of its calcareous silts was suddenly brought to a close by a change in condition of the sea and sedimentation of a different character began a new epoch.

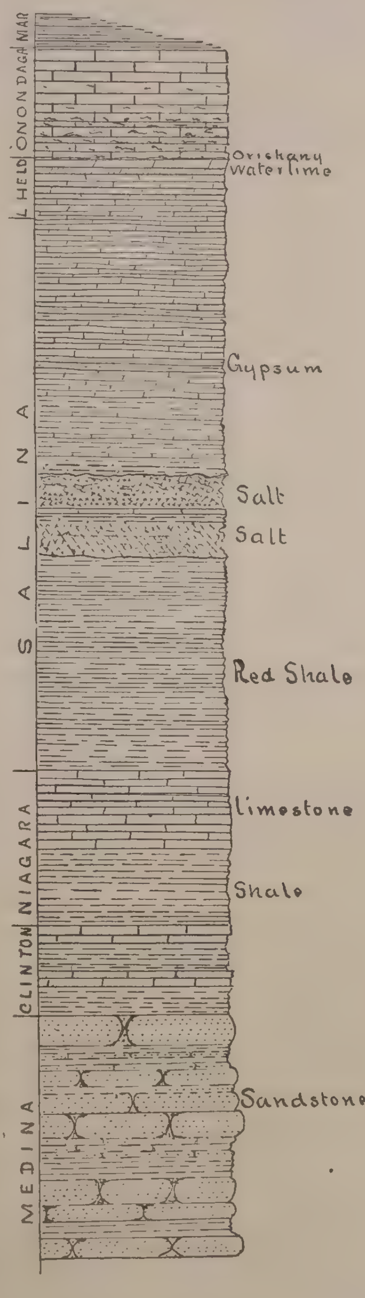


Figure 3. Diagram showing rocks exposed in central and western part of the salt district, from lake Ontario to the Helderberg escarpment.

The Salina or Salt group. This embraces beds of shales, limestones, rock salt and gypsum.

Next above the Lockport limestone is a thick bed of soft shales, bluish-grey, green and red, and bearing at some exposures a strong resemblance to the Medina shales, called on account of the predominating color, the Salina Red shales. They are best exposed in the vicinity of the Erie canal in Madison, Onondaga and Cayuga counties, and as far west as the Genesee river. They are generally buried under heavy drift deposits in the western part of the state, but are found in all of the drilled wells sunk through that horizon In the western counties some thin limestones are intercalated with the shales, and the latter lose to a large degree, the red color and become bluish grey or olive green, but still presenting the banded or variegated appearance observed in Onondaga county. In texture, the shales are soft and brittle, and on exposure rapidly turn to tough greasy clay. Occasional thin layers are slightly arenaceous, and in Onondaga county occur one or two layers of white and red sandstones, a few inches thick, very similar in character to the Medina sandstones.

The greatest thickness of the Red shales on the line of the northern outcrop of the beds, is in Onondaga and Cayuga counties. In the Gale well at Syracuse, which was begun near the top of the formation, they are 525 feet thick.

The area of surface exposure and the thickness of the beds diminishes rapidly towards the east across Madison county and the southern part of Oneida county, and they do not outcrop east of Herkimer county.

They also apparently become much thinner toward the west, but to what extent the difference is to be attributed to a lessened degree of sedimentation, and how much to changes in the character of the deposits, is not known. The changes are so gradual that in the absence of opportunities for careful examination of cross sections the thickness of the strata belonging to this division can only be estimated.

In the Le Roy well, the record of which has been published by I. P. Bishop, they are more than 300 feet thick; at Batavia about 250 feet and in the well at Gardenville, Erie county, not much more than 200 feet thick.

The deep wells drilled for salt usually end in, or at the bottom of the rock salt bed, but in one of the wells of the Standard Company, at Warsaw, the red shale below the salt was penetrated to the depth of 104 feet, and in the test well at the Livonia salt mine, 115 feet.

In the Ithaca test well, drilling ceased in shales of this formation 471 feet below the lowest bed of salt, and in the Morrisville well, 519 feet of these red and green shales were found overlying the Lockport limestone.

Next above the red shales as described are the rock salt beds of the state.

Although these beds are known to extend from the Oatka valley in Wyoming county to Morrisville, Madison county, and as far south, with increasing thickness, as wells have been drilled to their horizon, they nowhere come to the surface, and our knowledge of their condition and magnitude has been obtained entirely from the deep wells and mine shafts.

The wells to the number of nearly 200 are distributed over almost the entire area in which the salt beds are sufficiently near the surface to make it practicable to reach them by drilling, but opportunities for examination of the salt beds and adjacent rock strata in place are confined to a very small portion of the district.

Five vertical shafts about twelve by eighteen feet have been sunk as mine entrances, two of which are at the Retsof mine in the town of York, Livingston county, and one at the Greigsville mine, less than a mile distant.

The Lehigh shaft is twelve miles northwest, near Le Roy, and the Livonia shaft about the same distance east from the Retsof mine.

These shafts, as soon as the required depth was reached, were heavily timbered and lined to prevent the falling of loose fragments of rock, leaving only ten to twelve feet of that part of the salt bed in which the drifts and adits of the mine are located, accessible for examination.

The writer was present while the excavation of the Livonia salt shaft was in progress, from May 1891 to August 1892, when the bottom of the salt bed was reached at the depth of 1432 feet. Abundant opportunity was afforded for studying the material brought out, and frequent visits to the bottom of the mine were made for the purpose of determining the order of succession, and obtaining correct measurements.

The sinking of the Lehigh shaft at Le Roy, and of the Greigsville shaft was in progress at the same time and several visits to each were made for observation of any difference in the character and condition of the strata of the same horizon at the three localities. (See report of State Geologist for 1893.)

From information thus acquired and from that obtained from well records and the statements of owners and operators of salt plants, it is believed that the character and condition of the salt deposit is essentially the same throughout the entire district, the only material difference being in the thickness, and the number of intercalated layers of rock.

At the close of the epoch in which the red shales were deposited, the salt district of New York was covered by the wide shallow offshore borders of a great interior continental sea, protected from strong currents and the sudden ingress of large quantities of sea water; the conditions required for the crystallization of salt by solar evaporation existed, and the deposition of the salt beds was begun.

The crystals are very coarse and were formed in the mud, or embedded in it by the action of the waves, as there is no regular stratification in this part of the beds.

A greater or less proportion of rock material, limestone, shale and gypsum, is found in all of the lower bed, with which the salt crystals have apparently been violently stirred up and mixed, the whole mass having a coarsely granular or brecciated appearance.

The crystals in this "mixed salt," as it is called by the miners, are usually very clear and nearly transparent, though sometimes white and opaque.

In some parts of the beds, there is an almost entire absence of clayey or other matter except the salt, while in other parts they predominate, and irregular masses and layers of shale and limestone of considerable extent occur.

In the Livonia shaft this lower salt bed is overlaid by eight feet of stratified rock. It is soft shale or marlyte at the bottom, but the upper part is a thinly laminated impure magnesian limestone.

Both the shale and the limestone are full of seams and veins of salt, usually pink or red, and frequently in the larger veins it has a columnar structure.

Next above the limestone is the bed of stratified salt in which all of the four salt mines are situated. It is the lower part of the upper bed in the western part of the district, and appears to have been deposited in quiet waters. The lines of bedding are quite distinct, and may be traced for long distances, the shaly matter and the gypsum having been deposited with the thin layers of salt in varying proportion, or not at all.

Non-continuous layers of limestone or shale several inches thick sometimes occur, but they are not common, and the whole amount of impurity in the stratified salt is probably not more than 2 or 3 per cent of the whole bed The crystals are much smaller than those in the "mixed salt" and vary considerably in size in different layers. Above the stratified salt, a layer or mass of mixed salt occurs of the same character as that below.

The contact line between these two beds is exceedingly uneven and is only marked by a change from the laminated to the mixed condition of the material.

It is probable that the bed of stratified salt was orginally much thicker than now, and that before it had become thoroughly hardened the upper portions were broken up by the action of the waves and re-deposited in a mixed condition, the disturbance of the layers reaching to greater depths at some places than others.

Distributed through this upper layer are masses of rock, generally composed of gypseous shale and containing more or less salt in fine grains. When a fragment of this rock is placed in water or exposed to damp air the salt is dissolved, and soon there remains only a quantity of greenish or bluish clay or dust and small particles or flakes of gypsum.

Irregular and non-persistent layers of hard dark magnesian limestone also occur, especially toward the top of the bed, They sometimes have a thickness of two or three feet and appear to have been formed above the salt and to

have settled down into it. They are full of seams and grains of salt, and when subjected to the dissolving action of water, either separate into angular fragments in which there are many irregular cavities, or become reduced to the consistency of dark grey sand.

The roof of the salt bed is composed of large and small blocks, usually of gypseous shale, of the character described, the spaces between the blocks sometimes several inches in width, being filled with salt.

These veins were found to extend upward through shales and limestones, coalescing or branching out, twenty-one feet into the overlying strata at the Livonia shaft and more than 200 feet at the Lehigh shaft.

The salt in these veins is usually columnar or in crystals about the size of those in solar salt, and, in the shales, is frequently colored red, owing to the presence of iron. At the Greigsville and Lehigh shafts some of this vein salt is blood red. Thin veins and seams of gypsum are also abundant in the rocks and sometimes have the same red color.

Veins sometimes occur in which the matter adjacent to the walls is gypsum, and a layer of salt forms the middle portion.

The existence of these veins is the cause of much trouble in the salt wells.

The lower end of the tubing through which the brine comes to the surface, is placed in the lower part of the bed in order to reach the fully saturated brine which increases in weight as it takes up salt, and consequently sinks to the bottom of the cavity that is rapidly formed by the removal of the salt. The dissolution of the salt releases the embedded fragments of rock and gypsum and, except such small particles as the upward current in the tubing may carry to the surface, they are deposited on the floor of the reservoir. After a time, as this process is continued, the heavier strata overlying the salt lose their support and disastrous cavings take place, heaping the debris about the bottom of the tubing and preventing the inflow of the brine, frequently making it necessary to drill out the well, and instances have occurred where the tubing has been broken off by the falling rocks. As these cavings are known to occur in all parts of the salt district, the inference is warranted that the condition of the salt bed and also of the superjacent rocks is the same over the whole district.

The total thickness of the rock salt beds, including the interstratified layers of shale and limestone, in the southern part of the Oatka valley, is from 100 to 135 feet. At Silver Springs it is 145 feet, and at Castile 190 feet.

They gradually thin out toward the north, and do not reach beyond the latitude of Batavia, Le Roy and Caledonia.

In the Genesee valley, in a well on the Retsof mine property, the total thickness of the salt bearing strata was 124 feet, which includes two beds of rock, one twelve feet and the other three feet thick, and this record may be taken as showing the average thickness in that vicinity.

At the West Bloomfield and Bristol wells in Ontario county, but one bed eight to fifteen feet thick was found. At Naples, the bottom of the well is in the second bed of salt, sixty-three feet below the top of the upper one. A rock stratum separates the beds.

At Watkins the drill penetrated 100 feet of the salt strata, but did not reach the bottom.

From the top of the upper bed of salt in the Ithaca test well to the bottom of the seventh or lowest one, is 470 feet. This measurement includes six beds of rock with an aggregate thickness of 222 feet; the seven beds of salt together being 248 feet thick. The greatest thickness in the Solvay wells at Tully was found in Well No. 1, Group B, where it was 318 feet. At Morrisville, Madison county, it is but twelve feet.

That part of the bed that lies within easy drilling distance from the surface is practically inexhaustible, and what the maximum thickness is of the salt formations deeply buried under the hills and elevated tablelands of Cortland, Chenango and the southern tier of counties, where they doubtless exist, may never be known, but it must be enormous.

Overlying the salt deposits there are 250 to 300 feet of shales and magnesian limestones that contain the great deposits of hydrous calcium sulphate or gypsum found in Madison, Onondaga, Cayuga, Seneca, Ontario, Monroe and Genesee counties.

The shales are usually olive, bluish grey or ashen colored in comparatively thin beds, and dark, blue grey, gypseous shales or "plaster rock" in two or more heavier beds of very uneven thickness, the greatest being the upper gypsum bed at De Witt, Onondaga county, which, including some intercalated limestones, is 65 feet thick.

Considerable quantities of anhydrite are also found at this horizon west of the Genesee river.

No red shales have been found at exposures of this horizon east of the Genesee river, but a layer eighteen feet thick of highly colored red, green and mottled shale was found in the Lehigh shaft 140 feet above the salt bed.

For the reason that the section of country in which this formation constitutes the surface rock is mostly deeply buried under the drift, the continuity of the layers quarried at different localities is not well established, but whether continuous or lenticular, they are co-extensive with the salt beds.

The limestones are generally thin-bedded and laminated or shaly, though some layers are a foot or two thick and compact but quite brittle, breaking with a metallic ring, and splitting into concohoidal slabs.

When first quarried in the eastern part of the district, they are very dark-colored and bituminous, thin partings of carbonaceous matter separating the layers. After exposure they become a light ashen grey.

In the western counties, much of the limestone, when freshly excavated, has a dark reddish brown color that changes to a light pink grey on exposure.

Evidence that these rocks were deposited in water that contained salt nearly to the point of full saturation, is found in the hopper-shaped forms that occur at several horizons, and in the numerous cavities of the porous limestones which it is now known were once filled with salt.

The larger cavities are irregular in size and shape, and are more common on the surfaces of the layers, but others of a cellular character and from a microscopic size to three-eighths of an inch in diameter penetrate the rock in all directions communicating with each other and giving the limestones the pecular appearance indicated by the name applied to them by Vanuxem—"vermicular."

Fragments from a layer of very dark and apparently compact limestone in the Livonia shaft thirteen feet above the rock salt bed, changed on exposure to brownish grey, and after being immersed in the water for a few hours was found to contain numerous tubular cavities about one sixteenth of an inch in diameter.

The limestones also show many cracks, not like pressure cracks or extensive joints, but shallow and like those seen in sun-dried mud. When freshly excavated they are filled with salt, gypsum or black carbonaceous matter.

No fossils have been found in the red shales below the salt beds nor in the shales and limestones above described.

The Waterlime Formation. Next above the gypseous deposits are 100 to 150 feet of strata composed almost entirely of limestones, that constitute the "Magnesian deposit" of the early geologists. They are of the same general character as those in the beds below. The principal and perhaps the only reasons for separating them are the absence of the gypsum beds and the occurrence of the earliest traces of the existence of life subsequent to the Niagara epoch. The appearance of the little crustacean *Leperditia alta* in this horizon is evidence that the precipitation of the enormous quantities of salt and

sulphate of lime had so purified the waters of the interior continental sea that life could again be sustained in them.

Higher in the strata the limestones are generally purer, and other fossils appear quite abundantly.

In Onondaga, Cayuga and Ontario counties these upper layers of "blue limestone" have been extensively quarried for building stones and for the manufacture of quick-lime.

The large quantities of lime used by the Solvay Process Company, of Syracuse, in the manufacture of soda ash, is taken from their quarries in this horizon at Split Rock, where the rock is in layers from one to three feet thick.

It is blue-black in color and shows the lines of deposition very plainly. When burned, the bituminous matter which is the cause of the dark color is eliminated and an excellent quality of lime is produced.

At the mine shafts some of the rocks of this horizon had a brownish pink color, and contained a small amount of petroleum, which exuded in sufficient quantity to cover the surface of the stratum, and in the Lehigh shaft accumulated in the bottom to the amount of several quarts.

From a compact bed of fine, reddish brown, calcareous sandstone in the Livonia shaft there issued about 100 gallons per day of "bitter water" of so acrid a character as to produce a smarting sensation and violent inflammation when it came in contact with human flesh.

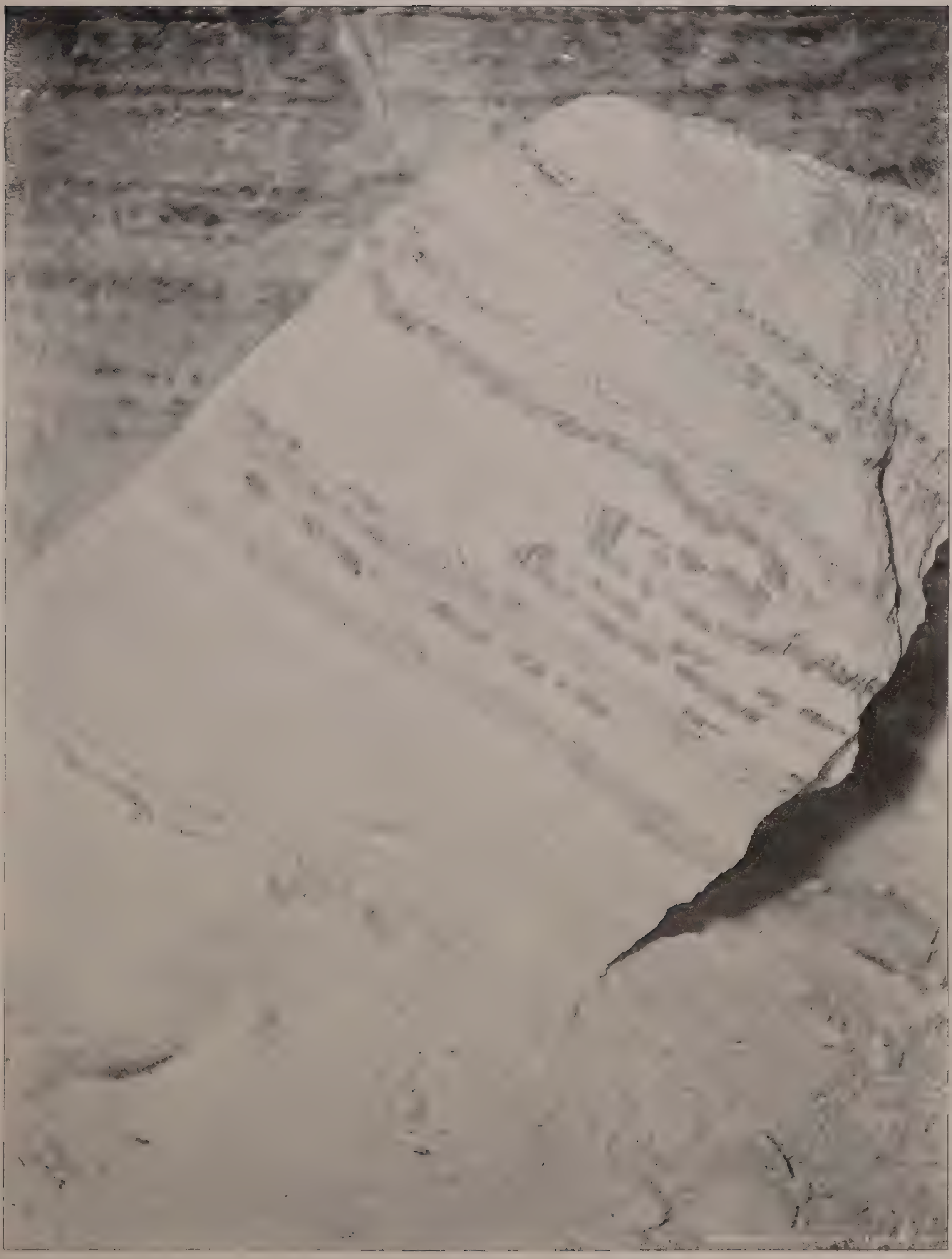
The beds of hydraulic limestone or "cement rock" which supply the large quanties of natural cement or water-lime produced in Onondaga county, and at Akron, in Erie county, are interstratified with the purer limestones in the upper part of these beds.

Though nearly black previous to exposure, the water-limestones weather quickly to a light drab. They are composed of carbonic acid, lime, magnesia, silica, alumina and iron in such proportions that when burned, ground and mixed with sand a mortar is found that will harden under water.

These rocks of this horizon are abundantly exposed in a large number of outcrops and quarries from Oneida to Erie county.

In the vicinity of Chittenango, Madison county, there are two layers of the water-limestone exposed in a quarry south of the village, each about four feet thick, separated by four feet of the blue limestone. They are in the same condition in the eastern part of Manlius, Onondaga county, and are about forty-five feet below the Oriskany sandstone. From this point westward the upper layer and the intervening rock become gradually thinner, while the lower layer increases in thickness. At Split Rock quarry in the same

PLATE IV.



Distorted bedding-lines in rock-salt. Livonia.

horizon, the upper layer thins out and comes to an end, while the lower one appears to be changed in character and to have become ordinary limestone. At Marcellus Falls, the water-lime layers reappear, the upper layer two feet ten inches thick and the lower one five feet three inches with thirteen inches of blue limestone between them. At Skaneateles Falls the beds have practically coalesced and are nine feet six inches thick, including four inches of blue shale in two layers.

They are quarried at several localities in Cayuga county, and can be easily recognized at all of the exposurses of their horizon in the central counties, but by reason of some difference in their composition they do not make good cement in Ontario, Livingston and Genesee counties.

Water-limestone is extensively mined and quarried, however, at Akron, Erie county, from a layer eight feet thick, that is separated from the "grey" (Onondaga) limestone by about five feet of hard, tough, clayey, drab limestone, known to the miners as "bullhead."

On account of the presence of the water-lime layers, these upper and purer limestones in which they are intercalated, have been collectively designated the "Water-lime Group" and have sometimes been regarded as constituting the upper division of the Salina period. As they are apparently synchronous, and to some degree coextensive with the lower division of the Lower Helderberg rocks of the eastern part of the state, and contain several of the characteristic fossils of that formation, they have by some been termed Lower Helderberg limestones, and are usually so designated in the shaft and well records.

Oriskany sandstone. In the eastern and central part of the salt district the next formation in the order of superposition is the Oriskany sandstone. It is composed of medium sized grains of nearly white quartz sand, having at different localities a yellowish, pinkish or brownish shade. It is usually more or less calcareous and very hard and firm, and suitable so far as durability goes, for building purposes. At some exposures, however, it is quite soft and friable. It is exceedingly variable in thickness.

At Oriskany Falls, Oneida county, it is twenty feet thick in two or three layers. Diminishing toward the west, it is but a few inches thick at Cazenovia, Madison county. Across Onondaga county, it decreases and disappears at Split Rock, then appears again and attains its greatest thickness in the salt district, twenty-five to thirty feet, south of Skaneateles Junction. It diminishes again toward the west, and at its last visible outcrop, in the village of Phelps, it is two feet thick.

In the Livonia shaft it formed a green and brownish nodular layer four and one half feet thick and carried fossils which indicated that it represented also the arenaceous sedimentation of the lower part of the Onondaga or Upper Helderberg formation. At the other shafts there is only a trace of it in the condition of a greenish nodular parting in the limestones.

Owing to the difficulty encountered in drilling it, this rock is readily recognized by well drillers whenever present in any appreciable thickness, as it usually is in the eastern part of the salt district.

At Tully it is fifteen to eighteen feet thick, and in the Ithaca test well thirteen feet.

Onondaga limestone. This formation is composed of layers from one inch to three feet thick of light, bluish grey, compact limestone, separated by thin partings of carbonaceous shale. In the eastern part of the salt district it has a total thickness of sixty to seventy feet, which is gradually increased to about 145 feet in Genesee county.

It is abundantly exposed along the rocky east and west ridge known as the Helderberg escarpment, of which it usually forms the crest, and the Lower Helderberg or Water-lime rocks the base.

In the reports of the Geological Survey of the Third and Fourth Districts, this mass of limestones was separated into two divisions, the lower being designated the Onondaga limestone, on account of its abundant exposure in Onondaga county, and the upper called the Corniferous limestone because of the presence of hornstone or chert in layers and nodules throughout the beds. This division has not of late years been generally recognized nor is it practicable except locally, and the entire formation has been more commonly known as the Corniferous or Upper Helderberg limestone.

The chert is quite unevenly distributed through the limestones, and at nearly every exposure, some layers are almost entirely free from it and are quarried largely for building and ornamental purposes. When dressed it has a semi-crystalline appearance, is handsome and durable. Large quantities of quick-lime are also made from it.

The extensive quarries on the Indian Reservation south of Syracuse are in this rock. It is also extensively quarried at Auburn and at Le Roy, and less extensively at Caledonia, Honeoye Falls, Phelps and other places.

To the drillers of salt wells the "top of the hard limestone" is an easily recognized bench-mark throughout the entire district, by which they know that the bottom of the soft shales has been reached, and that there remains 500 to 550 feet of rock to be penetrated before the salt bed is reached, nearly

all of which is hard drilling; and the passage through the flint is a distinct epoch in the history of every well.

As the black shales that overlie the Onondaga limestones are very soft, and offered but slight resistance to denuding glacial forces, the upper surface of the limestone along the crest of the Helderberg escarpment is uncovered in many places disclosing glacial scratches and polishings.

The movements that gave to the strata of the whole salt district a pronounced dip to the south and produced gentle undulations in many parts, fractured and dislocated the rigid Onondaga limestones, causing many small faultings and numerous fissures. Some of the latter that were so located as to receive the waters of some depression of the surface, have been so enlarged by the solvent action of the water on the limestone, that streams of considerable size disappear into them. Such sink holes occur for the entire length and breadth of the outcrop.

The disturbance of the strata is especially noticeable in the exposures of the rocks along the sides of the Onondaga valley and the adjacent country south of the Onondaga Salt Springs.

The foldings and fractures are on too extensive a scale to allow belief in a superficial orgin, and the dikes of kimberlite exposed on Green street hill in the city of Syracuse, two or three miles north of the escarpment and in an horizon that is below the gypsum beds, furnish abundant evidence that not all of the disturbance of the limestones can be due to crystallization in the gypsum beds or dissolution of the rock salt beds, and that the cause and effect of the movements were much deeper seated.

It is doubtless through these fissures that the waters of the higher land in the south part of the county find access to the rock salt and become partially saturated.

In the soft, clayey, red shales beneath the salt beds the fissures would be likely to close up, and the brine, under pressure from above, must follow the upward inclination of the strata until an outlet was found north in the basin of Onondaga lake.

It is not impossible that the brine springs of the Medina sandstones also derive their salt from the great Salina beds. The brine may find its way down through the Salina, Niagara and Clinton beds by means of the fissures, and thence upward through the porous layers of coarse sandstone to the surface several miles north of the north edge of the salt beds.

Between Caledonia and Le Roy, where the Onondaga limestone is the surface rock, there are many long, low, folds usually not more than two or

three rods wide and from one to five feet in height. Their axes have generally an east and west direction, but they are not straight and are very rarely parallel to each other. When not covered by the drift, it is plainly evident that they are anticlinal folds formed subsequent to the glacial epoch.

The salt beds have not been found to extend as far north as the line of outcrop of the Onondaga limestone, though approaching very near to it west of the Genesee river. In the eastern counties of the district they have not been found nearer than ten or fifteen miles south of the line of the Helderberg escarpment.

Hamilton Group. Next in order of upward succession are the argillaceous and sandy shales and thin limestones of the Hamilton period, at the base of which is the *Marcellus shale.* This formation is 150 to 200 feet thick in Onondaga county, where it has its greatest development. It diminishes toward the west, and is not more than sixty feet thick in the western part of Genesee county.

The contact line with the light grey Onondaga limestone is very distinctly marked by the abrupt change to black calcareous shales, or soft, thinly laminated, blue black limestone in a bed one to three feet thick that is succeded by a bed of fetid bituminous black shales, containing two or three rows of spherical concretions or septaria, from a few inches to two feet in diameter.

A stratum of dark grey, compact limestone one-half to three feet thick is interstratified with the black shales, and is known as the Goniatite limestone on account of the fine specimens of *Goniatites Vanuxemi* which it contains. As this rock is well exposed two miles west of the village of Manlius, it has sometimes been called the Manlius limestone. At Marcellus it is two and one-half feet thick and thirteen feet above the Onondaga limestone.

In the western part of the district a dark chocolate-colored limestone occupies a similar position in the strata, but carries a wholly different association of fossils. This has been termed the Stafford limestone.

It is well exposed at Le Roy in the east bank of Oatka Creek, where it is one foot eight inches thick and 29 feet above the Onondaga. Though it abounds in fossils, the goniatites are not in so good condition in the western part of the district. The intervening bed of black shale with concretions may also be seen to good advantage in the bed of the stream above the railroad bridges.

The cavities in some of the septaria in this horizon at Livonia and Le Roy were found to contain a small quanity of petroleum, and iron pyrites is abundant in both the shales and concretions.

The overlying shale next above the limestone is very black but becomes lighter colored by almost imperceptible gradations, and somewhat calcareous owing to the presence of great numbers of *Liorhynchus*.

The upper limit of the Marcellus is not established by any marked change in the character of the rock but is understood to be at the top of the beds that contain *Liorhynchus limitaris* abundantly.

Drilling through the Marcellus shale is easy and rapid, and there is only the difference in color to indicate to the driller a change from the Hamilton shales above.

This formation is the horizon of the mouths of the wells in which rock salt has been found in the village of Le Roy, the one at Teasel Hollow in Caledonia, and possibly the one at Batavia, are in the Marcellus shale.

East of the Genesee river the salt beds do not extend as far north as the line of Marcellus outcrops.

The light colored *Hamilton shales* come to the surface frequently over a belt of country averaging about five miles wide in the eastern part of the district and eight miles in the western part, and embracing a portion of most of the valleys of the Finger lake region, in which hundreds of deep ravines have been excavated in the sides of the hills where the strata are exposed to the greatest advantage.

In Madison and Onondaga counties this group of strata is about 1000 feet thick, if 200 feet be allowed for the Marcellus shale. It diminishes gradually toward the west, and in the Oatka valley, in Wyoming county, it is not more than 400 feet at the outcrop. The thickness increases at the rate of eight to ten feet per mile toward the south in the western part of the district, and fifteen to twenty feet in the eastern part.

Its greatest thickness in the salt district is 1142 feet as found in the Ithaca test well, and its least 395 feet, in the Pioneer well at Wyoming. At Livonia it is 517 feet thick.

The lower beds differ little from the upper part of the Marcellus, except in the character of the fossils, and in being somewhat lighter colored. They are generally dark brownish or bluish grey when freshly excavated, weathering to an ashen grey. The variation in color sometimes gives to the vertical walls of the ravines a banded appearance. These lower shales are very soft and disintegrate rapidly. The fossils are small and not usually very well preserved, except in the abundant calcareous concretions.

This part of the group is quite uniform in character throughout the district, and maintains its thickness more persistently than the upper beds. The strata aggregate about 400 feet in Onondaga county and are 233 feet thick at Livonia.

The upper part of these beds was termed by Professor Hall (1840), the Ludlowville shales.

These are succeeded by the Encrinal band, a formation of hard arenaceous and calcareous shales in which a layer of hard grey limestone one to two feet thick is interstratified. It receives its name from the large numbers of crinoids, whole and fragmentary, that occur in it. It is not known east of Cayuga lake and is much better developed from Seneca lake westward. Drillers of salt wells usually notice this rock by reason of its hardness, which is also the cause of its frequent exposure in the gullies. It is readily recognized and for that reason and on account of its persistent character it is of some importance as a bench-mark in the stratigraphy of the salt district. It is favorably exposed at the mouth of Tichenor's gully on Canandaigua lake and along the shore to the southward, also near the south line of West Bloomfield, and in ravines on both sides of Genesee river north of Geneseo, near Linwood in the town of Pavilion, in a railroad cut two miles west of East Bethany, on Murder creek at Griswold, at Darien, on Cayuga creek near Elma, and at North Evans on the shore of lake Erie, and at many other places.

Although the Encrinal limestone does not occur in Onondaga and Madison counties, the horizon is fairly well marked by a change in the character of the shales which become more arenaceous and contain large numbers of well preserved fossils, which are so abundant in some places as to form non-persistent calcareous layers of considerable extent, together with rows of concretions that contain beautifullypreserved fossils.

The shales are in thick beds, some of which are light or dark bluish-grey and more or less calcareous, others are olive and sandy, and in the eastern district a few layers of shaly olive or bluish sandstones are sufficiently firm to be utilized for building purposes. On the slopes of the hill sides at the south end of the valley of Onondaga creek these sandy layers appear, forming distinct terraces, the softer intervening beds having been removed by denudation, and they are exposed in similar escarpments near Delhi, and at other places.

Twenty to thirty feet at the top of the group are dark brownish and very soft shales that contain considerable iron pyrites and thin non-persistent layers composed of masses of fossils.

As the sediments above the Encrinal limestone decrease in thickness toward the west they become finer and lighter colored and much more calcareous. West of Seneca lake, limestones from an inch to a foot thick, that are sometimes persistent for many miles, are common in this horizon, and one or two of them are of such a character as to require careful observation to distinguish them from the Encrinal limestone.

The Retsof Salt shaft was begun on one of these layers 133 feet above the Encrinal limestone, to which it bore a very strong resemblance.

About 100 feet of the light blue fossiliferous layers at the top of the group are exceptionally well exposed along Little Beard's creek near the village of Moscow, Livingston county, and for this reason the beds of this horizon were early termed the Moscow shales.

The horizon of the mouths of the following shafts and salt wells is in the Hamilton shales:

In the Oatka valley:

- The Lehigh shaft.
- The well at the crossing of the Delaware, Lackawanna & Western and Buffalo, Rochester & Pittsburg railroads.
- The wells of the Pavilion Salt Company.

In the Genesee valley:

- The two shafts of the Retsof mine.
- The Greigsville shaft.
- The York well at York.
- The Livingston Salt Company's well at Piffard.
- The Genesee Salt Company's well at Piffard.
- The Phœnix Salt Company's well at Cuylerville.
- The Lakeville well at Lakeville.

The Ontario Gas and Improvement Company's wells at West Bloomfield and at Vincent (Muttonville) were also begun in this group.

In the eastern part of the district the Cayuga Lake Salt Company's wells at Ludlowville are begun in the upper shales.

The forty wells of the Solvay Process Company, at Tully, all have their beginning in the middle of the group and the test well at Morrisville was commenced in Hamilton shales 340 feet above the bottom of the formation.

Tully Limestone. Next above the Hamilton group and cropping out in many places along and on both sides of the southern boundary lines of Madison and Onondaga counties is the Tully limestone, so called from its favorable exposure in an escarpment on the west side of the valley in the town of Tully, Onondaga county.

It is an exceedingly hard, dark blue-grey limestone, in layers one to three feet thick, some of which are highly schistose, while in others the rock is brittle, breaking into sharp angular fragments. The whole bed is too impure for profitable use in the manufacture of quicklime, and too hard and brittle to be of much value as building stone.

It is the highest persistent limestone formation in the rocks of the salt district, being separated by more than a thousand feet of soft shales from the Onondaga limestone.

On account of its isolated position and peculiar characteristics both lithologic and paleontologic, it is easily recognized and its position in the outcrops readily traced.

Its greatest thickness is about thirty feet, which it attains in the southern part of Onondaga county and in the ravines near the head of Skaneateles lake.

It is exposed for about ten miles on both sides of Cayuga lake, dipping beneath the water three or four miles from the head, and is also seen on both sides of Seneca lake between Willard asylum and North Hector, and on the Keuka lake outlet, and in several ravines in the towns of Torrey and Benton, Yates county.

It diminishes in thickness westward from Onondaga county. On the shores of Cayuga lake it is fifteen to eighteen feet thick, and along Seneca lake eleven to fourteen feet; in the ravine at Bellona seven feet, and at its most westerly exposure which is in the bed of a small stream in the southwest corner of the town of Gorham, Ontario county, it is thirty-one inches thick in two layers, the upper one three inches and the lower one twenty-eight inches in thickness. It does not appear on Canandaigua lake, three miles to the east, though that horizon is exposed for several miles along both sides.

No limestone occurs in the horizon of the Tully in the western part of the salt district, but the contact line of the bluish grey Hamilton shales with the Genesee black slate is distinctly marked and easily recognized when exposed. Wherever the horizon has been exposed for a length of time, a stain of iron rust makes the contact line more noticeable. This stain is

caused by the oxidation of a thin layer of iron pyrites, occupying the position of the Tully limestone, and almost continuous from Canandaigua lake to lake Erie. It appears to have been deposited in lenticular patches, from a few square rods to several acres in extent, that sometimes coalesce and at others are separated for a short distance. It is never more than four inches thick and generally between one and two, very hard and heavy. When freshly broken it is of a brassy yellowish white and contains, somewhat sparsely, small *Goniatites*, *Chonetes* and other fossils. It is usually disintegrated for a few inches where exposed to the atmosphere, but is preserved under water. It is uniform in character and condition for the entire length of its line of outcrop in the salt district.

Its exposures are seen in many ravines and along the shores of Canandaigua lake, at the cascade in Fall brook near Geneseo, and in several ravines north of Moscow, at Griswold and Darien in Genesee county, at Iron Bridge mills on Cayuga creek in Erie county, and at many intermediate points

At Ithaca, the Tully limestone is 1774 feet above the top of the salt, and at Tully, 1675 feet.

At the Livonia shaft the pyrites layer occured at 1089 feet. At the Lackawanna well near Mt. Morris, 1117 feet, and at the Crystal salt well, near Warsaw, 1117 feet above the salt.

The mouth of the Pavilion well, in which salt was reached at 1019 feet, is very nearly in the horizon of the Tully limestone.

Genesee slate. This formation extends entirely across the salt district from east to west, but is much more characteristically developed west of Seneca lake, and receives its name from the Genesee river and valley where it is abundantly exposed.

In the hills south of the Tully salt wells, this formation appears as a mass of black carbonaceous laminated shale thirty to forty feet thick resting on the Tully limestone. Its thickness increases to about 100 feet on Cayuga lake and 150 feet on Seneca lake. In this region it contains a few septaria, but is otherwise very uniform in character It is highly developed in the vicinity of Canandaigua lake and attains a thickness of about 200 feet.

Several peculiar layers of very dark, hard limestone occur near the middle of the formation, separated by thin layers of shale. They are composed almost entirely of the shells of a minute pteropod, *Styliolina fissurella*, and are collectively known as the Styliola band. Some of the layers are very even and compact, while others are concretionary and nodular, and at some localities quite shaly. Plant remains, crinoids, fish remains and other

fossils are abundant at this horizon. This limestone band is of considerable value as a bench mark, as it is exposed in many places and is easily recognized. The most easterly exposure is at Foster's gully in Middlesex, Yates county. It is seen in the Seneca gully and elsewhere along the shores of Canandaigua lake, and in Mill gully, in the town of Richmond, Ontario county. It forms the crest of the falls in Fall brook, Geneseo, and in the ravine near Moscow. The dam across the Genesee river at Mt. Morris is built upon it. It is exposed in a small ravine two miles north of Wyoming, and at Griswold, Darien, on Cayuga creek, Erie county, at Iron Bridge mills, and at numerous other localities. It is three to five feet thick in Ontario and Livingston counties, diminishing toward the west to a single layer eight inches thick on the shore of lake Erie, its position in the middle of the Genesee slate being maintained the whole distance.

The Styliola band divides the Genesee slate into two parts of about equal thickness. The lower part is composed principally of densely black slaty shale, with a conspicuously jointed structure, the joints being one and one-half to two and one-half feet apart and crossing each other so as to form rectangular or diamond shaped blocks. Above the Styliola band the shales are mostly blue black and less slaty. Thin layers of the more bituminous variety are interstratified at intervals of four to six feet and a thicker stratum of the same is found at the bottom of the beds next to the Styliola limestone and another at the top of the formation. Spherical concretions of all sizes up to three feet in diameter, in rows or isolated, are found in large numbers in these beds.

In Ontario and Yates counties there are a few feet of olive shales and bluish flags just beneath the upper black bed, that have the character of transition shales between the Genesee and Portage rocks.

The black bed thirty to forty feet thick at the head of Canandaigua lake has sometimes been called the Lower Black Band of the Portage Group.

The "transition" beds thin out toward the west, and all of the black shales up to the base of the Cashaqua shales are usually considered as belonging to the Genesee shales. The total thickness of the formation is 135 feet in the Genesee valley, 100 feet in the Oatka valley, and but twenty-four feet at North Evans on lake Erie.

The wells of the Royal Salt Company, at Mt. Morris, and of the Lackawanna Salt Company, two miles west of Mt. Morris and the Moulton well at Pearl Creek are the only salt wells that have the Genesee as the surface rock.

Portage Group. The next formation in upward order of succession is the Portage group, which is composed of light and dark shales, thin flags and heavier bedded sandstones and has an aggregate thickness in the eastern part of the salt district of 1200 to 1300 feet, and 800 to 1000 feet in the Genesee and Oatka valleys.

It constitutes the surface rock over a considerable portion of the territory in which the producing wells of the salt district are located.

In the eastern part of the district the lower beds are mainly light colored sandy shales or flaggy sandstones, but include also strata of finer and softer fissile shales, very dark brown or black in color.

At Ithaca two layers of sandstones, together about four feet thick, are at the base of the group and above them are alternate strata of shales and sandstones aggregating 1300 feet in thickness that are considered on paleontological grounds to have been deposited in Portage time. A part of these beds 250 feet thick, the bottom of which is about 350 feet above the top of the Genesee, contains an association of fossils entirely different from that found in the remaining Portage beds above and below it. This subdivision is well defined about the head of Cayuga lake and eastward in Cortland and Chenango counties it thickens to such a degree as to represent almost completely the sedimentation of Portage time.

These beds were termed by Professors Hall and Vanuxem, the Ithaca group. Its limits are obscured on Seneca lake and have not been clearly traced west of it.

In the Naples valley at the head of Canandaigua lake, the shales are softer and generally lighter colored, and the sandstones thinner than in the localities last mentioned, and the outlining of the divisions, so distinctly marked in the Genesee river section, is begun.

At the base of the group there are 230 feet of soft olive and light blue shales, in which are intercalated a few thin sandstones. The lower part of these beds is quite barren, but fossils are common in the upper part.

Twenty-two feet of densely black fissile shale separates these Cashaqua beds from the darker and harder shales, and thin, hard, blue sandstone flags, that correspond to the Gardeau flags and shales of the Genesee river, and which have an aggregate thickness of 450 feet.

At the top of the group the sandstones are fairly well developed, consisting of layers of blue sandstone one to three feet thick separated by a few inches of hard shale, and having an aggregate thickness of nearly fifty feet. If these sandstones are coextensive with the original Portage sandstones of the Genesee valley, the thickness of the entire Portage group is approximately 650 feet in the Naples valley.

The exposure of these rocks in the gorge of the Genesee river from Mt. Morris to Portageville, from which the group derives its distinctive appellation, is but a comparatively short distance from the salt wells in the southern part of both the Genesee and Oatka valleys, and a description of the rock section there will apply to the whole of the western part of the district.

As previously stated, the dam at Mt. Morris is built upon the Styliola limestone.

Above it, and exposed on both sides at the mouth of the gorge, are the blue-black upper Genesee shales capped by a bed of densely black and bituminous non-fossiliferous shales, the whole mass having a thickness of about 100 feet.

The top of these black shales come down to the water level a mile or two up the river, and above them is exposed a band of soft clayey bluish-grey and olive shales 150 feet thick, in which there are no sandstone layers, but rows of flattened, impurely calcareous concretions that weather to a yellowish brown, appear at intervals of from two to five feet.

This grey band is uniform in character from top to bottom, and the upper and lower limits are plainly marked by the contrast of its light color with the black slates above and below. It is abundantly exposed near the Craig Colony (Son Yea), five miles east of Mt. Morris, along Cashaqua creek, and was hence termed by Professor Hall the Cashaqua shales.

The thickness of the grey band diminishes gradually toward the west, On lake Erie, at North Evans, it is thirty-two feet. It is exposed in the mouth of the small creek in the village of Wyoming and about the mouth of the old Globe Salt well, and also in the bed of the creek one mile south of Wyoming on the east side of the valley.

Overlying the Cashaqua beds is a band of black shale about twenty-five feet thick which is succeeded again by a mass of dark blue and black shales, with which thin sandstones or flags are abundantly interstratified, the whole being about 600 feet thick, and known as the Gardeau flags.

In the lower half of these beds the shales are very dark, and thick beds of black slates occur at frequent intervals, while the flags are few and thin, but toward the top, the shales are mostly light bluish-grey or olive and the sandy layers but a few inches apart.

The dark beds are exposed in the vertical cliffs and escarpments along the Genesee river from Gibsonville to near the foot of the lower Portage falls, and the upper division from the latter point to the top of the upper falls.

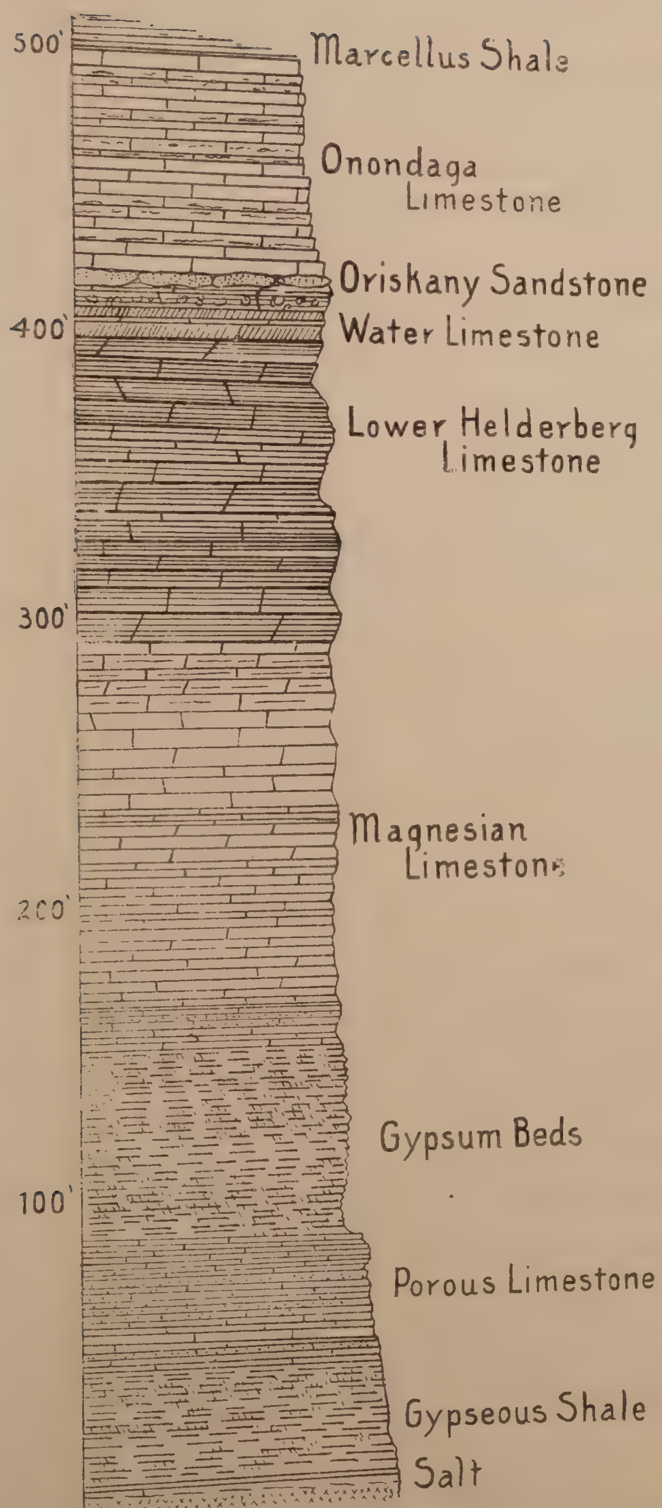


Figure 4. Section from the top of the Onondaga limestone to the salt.

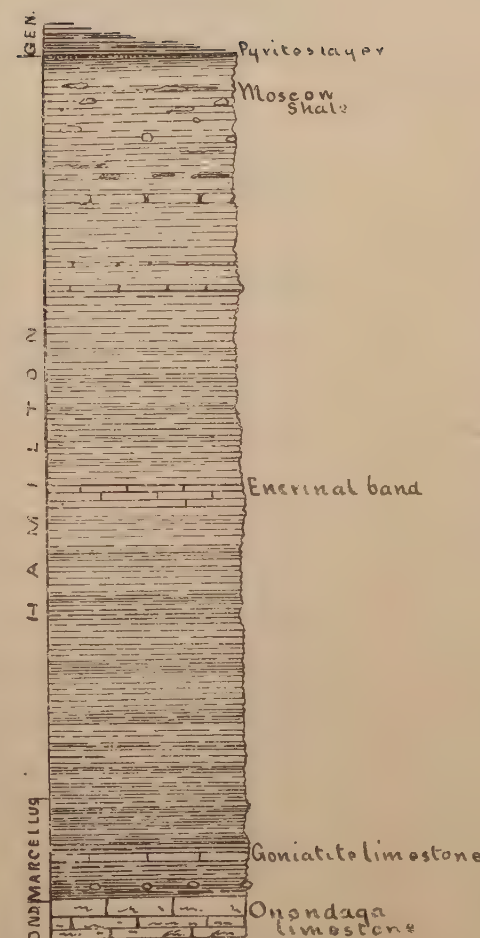


Figure 5. The Marcellus and Hamilton shales in the western part of the salt district.

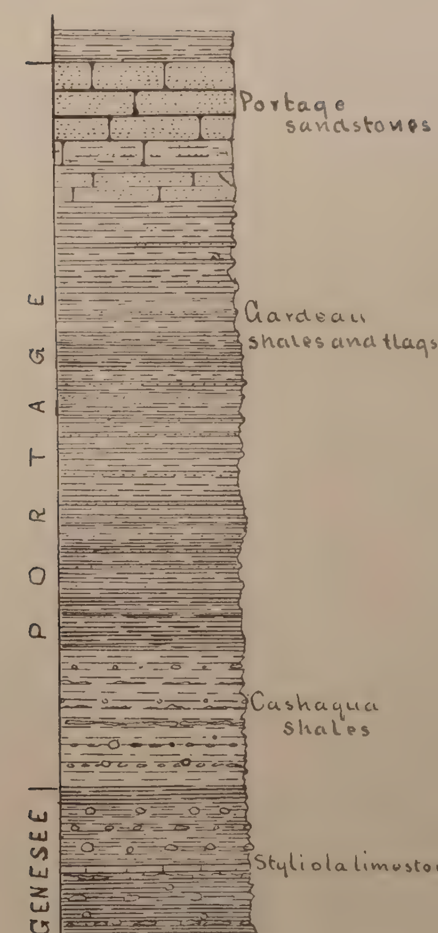


Figure 6. Section of the Genesee slate and Portage group in the western part of the salt district.

Westward the proportion of black shale increases in both the upper and lower beds, and the sandy layers diminish in numbers and thickness, and this tendency is manifest from the eastern limit of the district to lake Erie.

The highest subdivision of the Portage group is the Portage sandstones, which are best exposed and developed immediately above the upper Portage falls, where they are 185 feet thick including twelve feet of hard blue shales in three unequal layers.

The sandstone is in layers from two to ten feet thick separated by very thin shaly partings. It is light blue-grey when freshly broken, assuming a slightly yellowish tinge after long exposure.

In a majority of the layers the rock is compact, durable and valuable as building stone, and has been considerably quarried for that purpose in the vicinity of Portage falls, and at Nunda, Castile, Rock Glen and other places.

At some horizons the sandstone has a laminated or coarsely shaly structure or is soft and blocky.

Eastward from this locality the formation is less distinctly developed, but whether the change is due to a diminished quantity of sediment or to a difference in the character of the deposits is not as yet definitely established.

Westward from Portage across Wyoming county the formation is well developed but diminishes rapidly in thickness. It is well exposed in the vicinity of Rock Glen at the south end of the Oatka valley, and in the upper part of the ravine west of the village of Varysburg in the Tonawanda creek valley where the beds aggregate seventy feet in thickness.

The salt wells in the Oatka valley that are located on the rocks of the Portage group are the Globe well, the Pioneer well, the wells of the Crystal Salt Company; the Miller Salt Company; the Atlantic Salt Company; the Warsaw Salt Company; the Gouinlock Salt Company; the Hawley Salt Company; the Empire Salt Company; the Eldredge Salt Company; the Kerr Salt Company. Other wells are also located in this group; those at Nunda, Dansville, Livonia, Naples, and Dundee; the Glen Salt Company's wells at Watkins; the Ithaca Salt Company's wells at Ithaca, and the Ithaca test well.

Chemung Group. The shales and sandstones of the Chemung group are the surface rocks over nearly all that part of the state lying south of the line of outcrop of the Portage sandstones.

The bottom of the group is so far above the salt beds in the eastern part of the salt district, that it may be considered as being for practical purposes beyond its limits.

West of the Genesee river, however, several salt wells are located south of the upper line of the Portage sandstones, which since 1842 have been regarded as the top of the Portage group.

In Wyoming county there occurs immediately overlying the sandstones a bed of soft, light, bluish-grey shales nearly 100 feet thick, with concretionary calcareous layers at frequent intervals, and a few thin layers of bituminous black shale, the whole mass resembling strongly the grey band at the base of the Portage. Fossils are exceedingly rare, and such as do occur are nearly all of the same species as are found in the Portage soft shales. This bed is well exposed at Wiscoy and in some small ravines on the eastside of the Genesee valley in the vicinity of Rossburg.

Above these beds a succession of sandstones and shales come in that contain typical Chemung fossils abundantly.

The geologic horizon of the mouths of the salt wells at Silver Springs, Bliss, Eagle and Castile is in the lower part of the Chemung group.

THE FAUNAS OF THE HAMILTON GROUP

OF

EIGHTEEN-MILE CREEK AND VICINITY

In Western New York.

COMMUNICATED

By AMADEUS W. GRABAU.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
BOSTON, MASS., *Dec.* 14, 1896.

Professor JAMES HALL, *State Geologist:*

SIR. — I have the honor to transmit herewith for publication, an account of the Faunas of the Hamilton Group of Eighteen-Mile Creek and Vicinity.

Respectfully yours,

AMADEUS W. GRABAU.


MAP
of the
TOWNSHIP OF HAMBURGH
Erie County, N.Y.
showing the important exposures
of the
HAMILTON GROUP.
1896.
SCALE OF MILES.
0
1/2
1
2
3
78° 55'
42° 45'
LAKE ERIE.
Woodlawn
Blasdell
Rush
Creek
Big Tree
Bay View Cliff
Bay View
Mann's Point
Athol Springs Cliff
Athol Springs
Morse Creek
Avery's Creek
Hamburgh-on-the-Lake
Erie Cliff
Road
Shore
Wanakah
Lake
Wanakah Cliff
Old Gorge
Idlewood Cliff
Eighteen Mile Creek
Sect A
Sect B
Sect C
Sect D
Sect E
Sect F
Sect G
Sect H
South Shore Cliff
Pike Creek
North Evans
Lake View
Idlewood
Eighteen Mile
Eighteen Mile Creek [Gorge not represented]
Hamburgh

THE FAUNAS OF THE HAMILTON GROUP

OF

Eighteen-Mile Creek and Vicinity.

By Amadeus W. Grabau.

Introduction.

The investigations on which this paper is based, were begun in the early summer of 1895, and continued with more or less interruption to the present date. Several months of field-work during the summers of 1895 and 1896 furnished the necessary material and data for study during the succeeding winters. These studies were carried on in the geological laboratory of the Massachusetts Institute of Technology, where the greater portion of the collections was deposited.* The works most frequently consulted in the preparation of this paper, were those of Professors James Hall, John M. Clarke and H. S. Williams. To the writings of Professors Clarke and Williams, I am especially indebted for suggestions of methods of work, etc. Other acknowledgments are made in the text.

In the field I have had the constant assistance of Mr. P. L. Grabau, and for advice and suggestions I am indebted to Professors Alpheus Hyatt, W. O. Crosby and W. H. Niles.

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* This paper was originally presented to the Faculty of the Massachusetts Institute of Technology, as a thesis for the degree of Bachelor of Science in the Department of Geology, May, 1896. It was subsequently enlarged, and read at the Buffalo meeting of Section E, of the American Association for the Advancement of Science, August, 1896.

I. STRATIGRAPHY OF EIGHTEEN-MILE CREEK AND ADJACENT TERRITORY.

The portion of Eighteen-mile creek here under discussion, lies between the railroad bridge at North Evans station and the shore of lake Erie. (See map, Plate I.) The distance between the two points in a straight line is something over a mile, but the meandering of the stream has greatly increased the length of the gorge. Eight sections are exposed, no two extending in the same direction, and therefore no two showing the same dip of the strata. The true dip is between one and two degrees to the south-west.

There are six sections along the lake shore which exhibit the strata of the Hamilton group; five north and one south of the mouth of Eighteen-mile creek. These are:

1. Bay View cliff.
2. Athol Springs cliff.
3. Erie cliff, including the sections on Avery's creek.
4. Wanakah cliff.
5. Idlewood cliff.
6. South shore cliff, No. 1.

These are described below with those of Eighteen-mile creek. The following formations are exhibited in the sections (See also diagram, Plate II):

Chemung group	Portage stage	Naples shales
		Genesee slate
Hamilton group	Hamilton stage	Moscow or upper shales
		Encrinal limestone
		Hamilton or lower shales
	Marcellus stage	Transition shales
		Marcellus shales.

CHEMUNG GROUP — *Portage stage.*

Naples shales.

The term "*Naples shales*" was proposed by John M. Clarke in 1885, for the shales and arenaceous beds lying between the Genesee shales and the Portage sandstones;* that is, for the beds carrying the peculiar *Naples fauna.*

* Bull. 16 U. S. Geol. Surv., p. 36.

In this region the upper part of these beds consists of black, fissile, much jointed and highly bituminous shales (the Gardeau shales of Professor Hall) of which about forty feet are exposed in the section near the railroad bridge. Owing to the dip of the strata, and the direction of the upper part of the stream, these rocks form the walls of the gorge for many miles above the bridge. Overlying these are olive shales and arenaceous beds.

Below the black shales occur about thirty feet of greenish-grey shales, readily weathering into clay, and embracing many layers of concretions. These are the Cashaqua shales of the New York reports.

Genesee slate.

These beds have a total thickness of about nineteen feet. The upper nine and one-half feet are black, fissile shales, resembling some of the Gardeau shales, but they are usually more stained by iron oxide, owing to the decomposition of pyrite, which is present in great abundance. Below the black are the grey Genesee shales. These are eight and one-half feet thick, of a greenish grey color and include, near the base, several thin beds of black shale, as well as several thin limestone layers. Below these, and frequently forming the base of the Genesee formation in this region, is a limestone bed six inches in thickness, representing the *Styliola layer* of Clarke, which is literally composed of the shells of *Styliolina fissurella* (Styliolina limestone, Dana's Manual, 4th ed.) Immediately beneath this bed, in some of the sections, and often united with it into a single bed, is the *Conodont layer* of Hinde,* which, as will be shown later, belongs to the Genesee rather than to the Hamilton stage. Occasionally a few inches of barren shale, sometimes with spores, underlie the Conodont bed, and form the base of the Genesee slate.

HAMILTON GROUP — *Hamilton stage.*

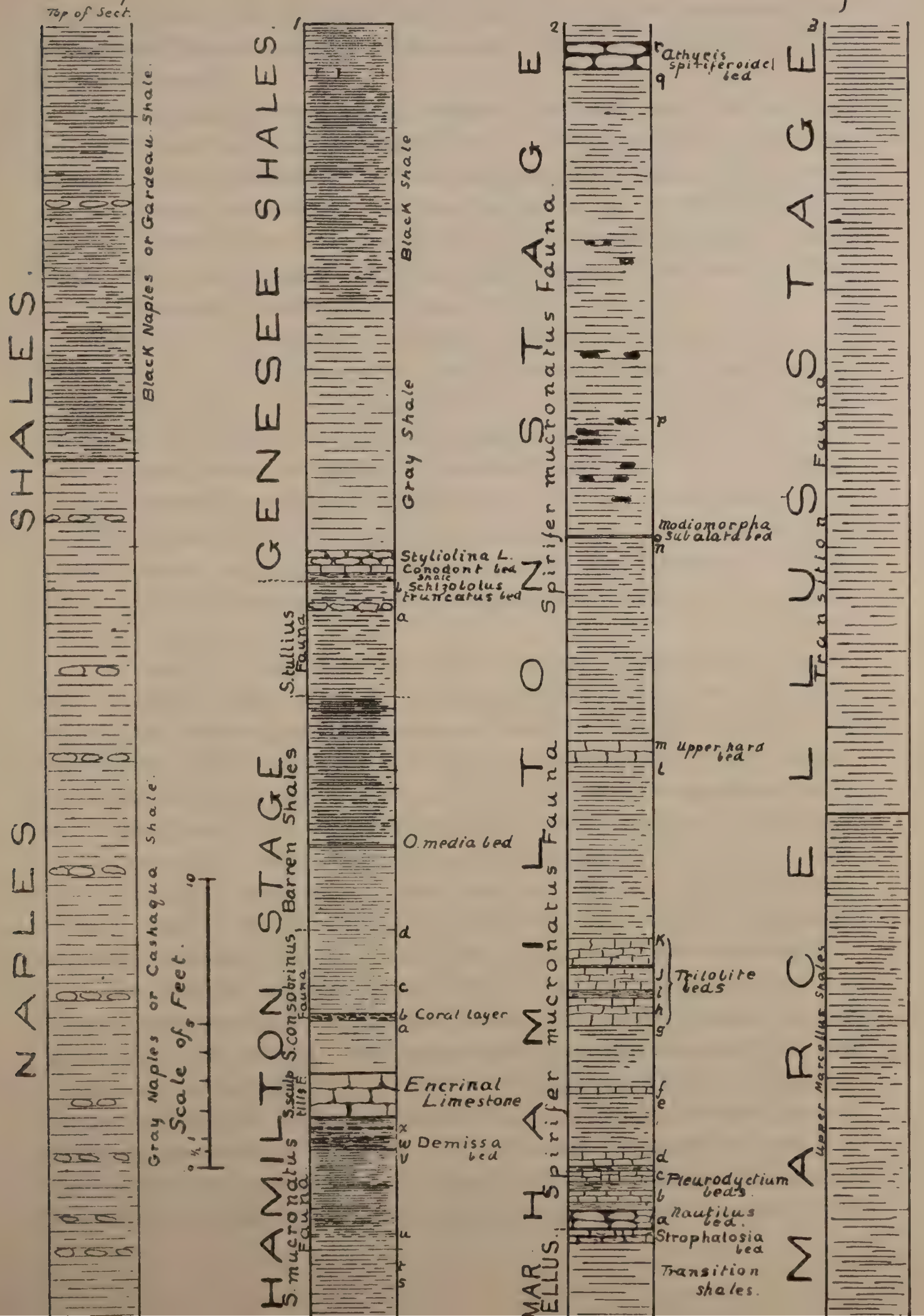
The *Moscow* or *Upper shales* have a total thickness of seventeen feet of which the upper twelve or fourteen inches represent transitional layers to the rocks above. The shales are grey or purplish-grey in color, somewhat calcareous, and poorly laminated. They embrace several courses of concretions, and are not very rich in organic remains. The presence of plant remains, and the general condition of the beds, indicate rather shallow water. This is furthermore indicated by a well-worn quartz pebble and a worn fragment of a *Spirifer granulosus* both of which were found in

*G. J. Hinde, On Conodonts, etc. Quart. Journ. Geolog. Soc., Vol. XXXV, p. 352, 1880.

PLATE II.

Partial

Geological Section AT Eighteen Mile Creek and Vicinity.



the lower part of the Moscow shale. This shell has not otherwise been found in the Moscow shales of Eighteen-mile creek. but is abundant in the limestone beneath.

The *Encrinal limestone* has an average thickness of about one and one-half feet, occurring usually as a single layer. Where weathered, it is seen to be made up of comminuted organic remains, among which fragments and joints of crinoid stems predominate. In places the upper part of the bed is somewhat shaly, and it is in this part of the rock that lamellibranchs are chiefly found. The lower compact and semi crystalline portion of the rock contains heads of *Favosites Hamiltoniæ* and other corals.

While this is the condition existing at Eighteen-mile creek, and on the lake shore for some distance above and below the mouth of the creek, at Morse creek, seven miles north-east, along the strike of the bed, the lower portion of the limestone is of a shaly character. It is this portion of the rock which contains the corals; heads of *Favosites Hamiltoniæ* two feet or more in greatest diameter occurring with *Heliophyllum Halli* and *H. confluens.*

The specimens obtained from the Encrinal limestone seldom preserve their surface features, owing to the readiness with which they exfoliate. It is only where weathering has removed the surrounding matrix, that perfect specimens have been obtained.

Forming, as it does, a dividing line between the Hamilton shales beneath, and the Moscow shales above, and retaining its individuality throughout this region, this limestone becomes a convenient reference stratum, from which the subdivisions of the two shales can be measured, either upwards or downwards, and in the following pages it is so used, all subdivisions being referred to it as a datum plane. The bed is divided into blocks by two sets of joints, and every year many of these become undermined and fall to the foot of the cliff, where they often accumulate in great numbers. The lower face of the limestone is usually coated with a thick layer of iron sulphide (probably marcasite) from the oxidation of which the rock is usually much discolored.

The *Hamilton* or *Lower shales* differ in lithologic character from the Moscow shales mainly in their greater fineness, and probably a higher percentage of calcareous material. They are more fissile and their lamination is more pronounced and regular. The indications are of deeper and purer water during their deposition, and corresponding with these conditions, we have a greater abundance and variety of organisms. Several courses of concretions occur, but these are not as continuous as are those of the Moscow shales. The upper four inches of shale immediately underlying the Encrinal limestone were

found, wherever examined, to be destitute of fossils and generally of calcareous matter, being a soft, light grey rock, which, when taken from the bed, may be cut with a knife. On exposure it darkens and hardens, losing its plasticity. When soaked in water it becomes a tenacious clay or mud. This condition is probably due to the leaching out of the calcareous matter by the acidulated waters resulting from the oxidation of the iron sulphide, the shale thus losing its most important lithifying element.

The upper thirty feet or more of these shales are very uniform without any marked dividing layers. There are numerous concretions, arranged in horizontal layers, but, with the exception of the *Athyris spiriferoides bed*, they are never continuous for any great distance. The *Modiomorpha subalata bed*, twenty-five feet below the Encrinal limestone, is a continuous stratum of calcareous rock which may be traced for miles, but it never exceeds one or one and one-half inches in thickness, and consequently it is not a prominent feature of the cliffs. The first continuous bed which is sharply marked off lithologically from the shales, lies about thirty-two feet below the Encrinal limestone. This is a calcareo-argillaceous rock, in places a compact limstone, though usually of a more or less shaly character. It is from eight to ten inches thick, and forms a prominent band wherever exposed in the sections. Six feet below it is the first *Trilobite bed*, of similar lithologic composition and rich in trilobite remains. There are three of these beds separated by layers of shale, all grading more or less into each other, and having a total thickness of something over three feet. Five to seven feet below the base of the lowest trilobite layer, are three other calcareous layers. These are the *Pleurodictyum beds* of the succeeding pages. The lowest of these beds, a compact grey argillaceous limestone of a concretionary character, is again separated under the name of the *Nautilus bed*, this being the horizon of *Nautilus magister*, Hall.

Marcellus stage.

Immediately below the Nautilus bed is another continuous calcareo-argillaceous layer, resembling in lithologic character the Trilobite beds. This bed I have called the *Strophalosia bed*, from the great abundance in it of *S. truncata*. It forms a prominent and easily recognizable band six inches in thickness, and is another convenient reference plane for the beds above and below. Its position is a little less than fifty feet below the base of the Encrinal limestone, and it marks the final disappearance of the Marcellus, and the establishment of the Hamilton faunas.*

* This is the bed lettered *a* on Plate V of the Geol. of the 4th Dist. N. Y., 1843, mentioned on pp. 190 and 191 of the text.

PLATE III.

VIEW OF SECTION C, EIGHTEEN-MILE CREEK, LOOKING NORTH.

A. Hamilton shales; B. Encrinal limestone; C. Moscow shales; D. Styliola limestone; E. Genesee shales; F. Naples shales.

Transition Shales.

Thirty feet of the shale beneath the Strophalosia bed must be regarded as transitional between the Marcellus and the Hamilton, containing an intermixture of the fossils of both. Several courses of concretions are present in these shales, but fossils are not very abundant.

Upper Marcellus shales.

Only about fifteen or twenty feet of the upper Marcellus shales are exposed in the sections along the lake shore. The shale is uniform in texture, well laminated and brittle. Fossils are rare, consisting mainly of *Tentaculites gracilistriatus* and *Styliolina fissurella.* In the upper part of the mass, these are extremely abundant, in some places thickly covering the weathered surfaces of the shale. *Lunulicardium fragile* also occurs occasionally, and carbonized plant remains are sometimes found. Several hard calcareous layers containing *Ambocœlia umbonata* occur in the upper part of the mass.

The lower beds of this group, i. e. the black Marcellus shales, have not yet been examined and their description will be deferred to a future paper.

Description of the Sections.

Bay View cliff. This is the first cliff on the lake Erie shore south of Buffalo. It rises nowhere above fifteen feet, and exposes only the upper Marcellus shales. The jointing characteristic of all the shales in this region is well shown. The total length of the section is a little less than half a mile.

Athol Springs cliff. This cliff extends southwards from the Fresh Air Mission to Mann's point, a distance of about three-fourths of a mile. Its average height is about thirty feet, of which about fifteen feet near the northern end are of Marcellus shale. The cliff for some distance south of the Mission attains only about one-half its usual height, and the top is formed by hard layers of the Marcellus. These hard layers dip below the lake level near the southern end of the cliff, beyond which point the cliff presents only the transition beds. In a few places near the top of the cliff the Strophalosia bed appears. This cliff is separated from the next by a dry ravine, in which exposures are few.

Erie cliff. This cliff, beginning on the land of Mr. Avery, extends southward for a distance of about one and one-half miles. It rises nowhere much above thirty feet, and near the southern end it is much lower. The ravine of Avery's creek cuts it in two, and furnishes additional sections for observation. Twenty-six feet above the base of the cliff, the Strophalosia

bed appears as a prominent band. About eight feet of shale lie above it, but owing to the presence of much talus the Pleurodictyum beds are not generally visible, though on climbing the bank the Nautilus bed can usually be seen resting upon the Strophalosia bed. The presence of the Pleurodictyum beds is, however, indicated by the abundance of *P. stylopora* on the beach at the foot of the cliff. Specimens of *Nautilus magister* are also occasionally found, while the rock of the Nautilus bed, filled with *Ambocœlia umbonata* var. *nana* is of common occurrence.

Avery's creek. In the lower portion of the ravine of this stream the transition beds are exposed; the Strophalosia bed which terminates them also appears in places, though talus more or less obscures it. Where the Lake Shore road crosses the ravine, the Strophalosia bed appears in the bed of the stream, causing a small fall. The banks of the ravine above the fall are low, seldom rising more than five feet, but as the stream-bed rapidly rises, the successive layers overlying the Strophalosia bed are exposed. This is the best locality for collecting the fossils from the Pleurodictyum and Nautilus beds, and the shales between the former and the Trilobite beds are well exposed. The latter cause a series of rapids in the stream, half way between the lake shore and the railroad track, near which the upper hard layer is exposed.

Wanakah cliff. This cliff begins less than a mile and a half south of the termination of Erie cliff, the shore between the two being low, and more or less drift covered. The cliff soon rises to a height of about seventy-five feet, exposing in succession the Lower shales, from the Trilobite beds upwards, the Encrinal limestone, the Moscow shales, and the grey and black Genesee shales. The cliff in many places is almost perpendicular, and presents one of the finest sections to be found in this vicinity. At the base are the Trilobite beds which form a prominent bench for some distance along the shore. Owing to the direction of the section which swings around to the west, the Trilobite beds appear higher up in the bank as we go southward, the cliff at the same time becoming lower. The upper calcareous bed appears prominently in the cliff, being about half way up near the southern end. The *Modiomorpha subalata bed* also appears in fresh portions of the cliff, forming a narrow band. Its characteristic fossils may be best obtained in a little ravine near the middle of the section where the bed causes a small fall in the stream. At the lower end of the section the Pleurodictyum beds appear on the beach, the fossils being occasionally pyritized. Between this section and the next, is an old river gorge about 1,000 feet wide, and filled with till containing many Corniferous limestone boulders.

PLATE IV.

VIEW OF A PART OF THE SOUTH SHORE CLIFF, LAKE ERIE, LOOKING NORTH.

A. Hamilton shales; B. Encrinal limestone; C. Moscow shales; D. Styliola limestone; E. Genesee shales; F. Naples shales.

Idlewood cliff. This cliff extends from the drift filled gorge to the mouth of Eighteen-Mile creek, where its height is about fifty feet. The lowest beds exposed in this section are the shales beneath the Trilobite beds; the Pleurodictyum beds, though probably forming the base of the section, being covered by talus. The Encrinal limestone appears near the top of the bank, and above it are six feet of the Moscow shales. The total length of the section is about a mile, though parts of it are obscured by talus and vegetation.

The Eighteen-Mile creek sections. These sections, undoubtedly the most interesting and the ones most thoroughly studied, number eight in all, as follows:

Section A. This is the section which forms the left bank of the stream near its mouth. The lowest strata exposed are the Trilobite beds. The Encrinal limestone appears in the upper part of the bank, capped by about twelve feet of the Moscow shales. The total height of the section is fifty-six feet, and its length about one thousand feet.

Section B. This section, on the right bank of the creek, has a length of about twelve hundred feet, and a height of about fifty-five feet. It exhibits about thirty feet of the Lower shales, the Encrinal limestone, the Moscow shales and part of the Genesee shales, including the Styliolina limestone.

Section C. Only about nine feet of the Lower shales are exposed in this section, which also exhibits the succeeding strata, including twenty-five feet of the grey Naples shales. The section has a length of about seven hundred feet, and a total height not exceeding sixty-two feet. (Plate III).

Section D. The *Stropheodonta demissa bed* is the lowest exposed in this section, and its characteristic fossils may be obtained here in abundance. The Encrinal, Moscow, Genesee, and lower Naples beds form the upper part of the section. The length of the section is 2200 feet. Near its upstream end, a small fall is produced by the Encrinal limestone which extends across the stream.

Sections E, F and G. From two to four feet of the Moscow shales are exposed at the base of each of these sections, the upper portions being made up of the Genesee and Naples shales. The sections are respectively six hundred, five hundred, and three hundred and fifty feet in length. The *Conodont bed* appears as a thin band just beneath the Styliolina limestone in the last two of these sections. It does not form a stratum distinct from the Styliolina band, but is united with it.

Section H. Only about a foot and a half of the Moscow shales are exposed near the lower end of this section, the greater part of the section not showing them at all. The following are the measurements of the strata exposed above the Moscow shales.

Black Naples (Gardeau)	40 feet.
Grey Naples (Cashaqua)	30 feet.
Black Genesee	9.5 feet.
Grey Genesee	8.5 feet.
Styliolina limestone	.5 feet.
Conodont limestone	.25 feet.
Shale with spores	.25 feet.

The length of the section is about eight hundred feet.

First South Shore cliff. The part of the cliff here considered extends southward along the lake shore from the mouth of Eighteen-mile creek to Pike creek, a distance of about one and one-half miles. The height varies greatly in different parts of the section but does not exceed sixty or seventy feet. The strata dip gently southward, and while about forty feet of the Lower shales are exposed at the northern end, these have entirely disappeared at the southern end, where the Moscow and Genesee shales are alone seen in the cliff. In the highest portion of the cliff the Naples shales are exposed, while the Encrinal limestone forms a prominent bed throughout the greater part of the section. The Styliolina bed thins out southward, its thickness at the southern end of the section being less than an inch, the rock assuming a shaly character. The Moscow shales soon disappear from the section beyond the mouth of Pike creek, and the remainder of this and the succeeding sections on the lake shore show only the Genesee and Naples shales. (Plate IV).

Evidence of Disturbance.

Faults. Several small faults are shown in some of the sections. They are all reversed or thrust faults. One shown in section D, at Eighteen-mile creek, has a vertical displacement of about two feet, while several smaller ones shown in section A, have a vertical displacement not exceeding half a foot. A larger and more complicated fault is shown in the South Shore cliff, about a mile south of the mouth of Eighteen-mile creek. In the relatively rigid Encrinal limestone, complete separation along the thrust plane is produced, a vertical displacement of several feet resulting. In the Genesee shales the fault passes into a broken flexure, a crushed zone marking the plane of deformation (Plate V).

Folds. A single small anticlinal fold appears in the upper Moscow shale at the southern end of section F, in Eighteen-mile creek.

PLATE V.

FAULT PASSING UPWARD INTO A BROKEN FLEXURE.

The vertical displacement is 4 feet in the Encrinal limestone. The Moscow and Genesee shales are flexed and broken, in part standing vertical. The fault plane passes obliquely upward from right to left. (See Hall, Geol. Fourth Dist., p. 295, fig. 141, 1843). South shore cliff, no. 1; one mile south of Eighteen-mile creek.

II. THE VERTICAL DISTRIBUTION OF THE INVERTEBRATE FOSSILS IN THE HAMILTON GROUP OF EIGHTEEN-MILE CREEK AND ADJACENT TERRITORY.

CRUSTACEA.

TRILOBITA.

Genus **Phacops,** Emmrich.

1. PHACOPS RANA, Green.

1888, J. Hall and J. M. Clarke, Pal. N. Y., vol. 7, p, 19, pl. 7, 8, 8*a*.*

This is the most widely distributed and characteristic fossil in the Hamilton group of this region. It occurs throughout the mass, and usually is abundantly represented. I have found it in the lowest beds of the group on the lake shore, as well as in the transition beds and in the upper Marcellus shales. In these last mentioned beds it is, however, not very abundant. It is the characteristic fossil of the Trilobite beds occurring in them almost to the exclusion of every other fossil, but is mainly represented by cephala and pygidia. In the overlying beds this species is by no means as abundant as in the Trilobite beds, but it nevertheless is an important constituent of the fauna. In the Encrinal limestone it is a common form, and although the specimens are usually poorly preserved, they indicate by their size, that the species lived under favorable conditions. Two specimens measured, gave 40 and 50 mm., respectively for the greatest width of the cephalon. In the Moscow shales the size decreases somewhat but the individuals are abundant. Specimens have been found up to within a foot or eighteen inches of the Styliolina limestone.

Genus **Cryphæus,** Green.

2. CRYPHÆUS BOOTHI, Green.

1888, J. Hall and J. M. Clarke, Pal. N. Y., vol. 7, p. 42, pl. 16, 16*a*.

This species is usually associated in the Trilobite beds with the preceding, but is far less common. It is likewise mainly represented by cephala and pygidia. It is common, and occasionally abundant in various parts of the

*As the bibliography of each species is given in the work cited, no attempt has been made to repeat it here.

Lower shales, but occurs rarely in the Encrinal limestone, and is sparingly represented in the lower Moscow shales. It has not been observed in the upper portion of the Moscow shales. Below the Trilobite beds it is very rare, only a few fragments having been obtained. These show the existence of the species in the lowest Hamilton beds of this region.

2a. CRYPHÆUS BOOTHI, var. CALLITELES, Green.

1888, J. Hall and J. M. Clarke, Pal. N. Y., vol. 7, p. 45, pl. 16, 16*a*.

This variety is rare, being represented in the collections from Eighteen-mile creek by a few pygidia and cephala only, which were found in the Trilobite beds. Two pygidia from the Encrinal limestone are referred to this variety with some doubt.

Genus **Homalonotus**, Koenig.

3. HOMALONOTUS DEKAYI, Green.

1888, J. Hall and J. M. Clarke, Pal. N. Y., vol. 7, p. 7, pl. 2, 3, 4, 5.

This species is rare in the Hamilton group of this region. I have not found it at Eighteen-mile creek, but at Hamburgh-on-the-lake a few fragmentary specimens were obtained. It occurs in the lowest Trilobite bed, and fragments have been found in the Pleurodictyum and Nautilus beds.

Genus **Proetus**, Steininger.

4. PROETUS MACROCEPHALUS, Hall.

1888, J. Hall and J. M. Clarke, Pal. N. Y., vol. 7, p. 116, pl. 21, 23.

This species occurs in the Encrinal limestone. It is rare, though the specimens found are of good size.

5. PROETUS, sp.

A single glabella, approaching in outline that of *P. curvimarginatus*, of the Schoharie grit, was found in a fossiliferous layer six feet below the lowest Trilobite bed at Wanakah Cliff. The surface is strongly pustulose.

OSTRACODA.

Genus **Primitiopsis**, Jones.

5. PRIMITIOPSIS PUNCTULIFERA, Hall.

1860, *Leperditia punctulifera*, Hall, 13th Rep. N. Y., State Cab. Nat. History, p. 92.

1890, *Primitiopsis punctulifera*, Jones, Quart. Journ. Geol. Soc. vol. 46, p. 9, pl. 2.

Also 1891, Jones, Contr. Micr. Pal. pt. 3, p. 95, pl. 11.

This species is frequently abundant in certain thin layers. It occurs throughout the Lower shales, but has not been noticed above these. Associated with this species are frequently other Ostracoda.*

CEPHALOPODA.

Genus **Goniatites**, De Haan

7. GONIATITES UNIANGULARIS, Conrad.

1879, Hall, Pal. N. Y. vol. 5, pt. 2, p. 444, pl. 71, 74.

A single specimen beautifully pyritized, was found in a limestone band between six and seven feet below the lowest Trilobite bed, at Wanakah Cliff.

Genus **Nautilus** Breyn.

8. NAUTILUS MAGISTER, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 422, pl. 62, 107, 108.

This species was originally described as occuring "in some concretionary calcareous layers, in the upper shales of the Hamilton group, on the shore of lake Erie, in the town of Hamburgh, Erie county, N. Y." (p. 423). The original locality is Avery's creek and the cliff immediately adjacent on the lake shore, both north and south. The concretionary layers are those of the lowest Pleurodictyum layer (Nautilus bed) resting upon the Strophalosia bed. These beds are here referred to the *lower* part of the Hamilton group. The individual specimens are usually large, but they are not very abundant.

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* The following species have been described from the Hamilton shales of Eighteen-mile creek, but their precise horizons are not known: *Primitia seminulum*, Jones; *Entomis rhomboidea* Jones; *Strepula sigmoidalis*, Jones; *S. plantaris*, Jones; *Beyrichia Hamiltonensis*, Jones; *B. tricollina*, Ulrich; *Isochilina (?) fabacea*, Jones; *Aechmina marginata*, Ulrich; *Ctenobolbina minima*, Ulrich; *Moorea bicornuta*, Ulrich; *Bairdia leguminoides*, Ulrich, *Leperditia Hudsonica*. Hall, var. Jones.

Genus **Orthoceras**, Breynius.

9. ORTHOCERAS SUBULATUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 283, pl. 38, 84, 86.

This species is represented by a single specimen from the Encrinal limestone, and by two crushed specimens from the upper Moscow shales (2 ft. below the top). Another crushed specimen similar to the last was found three feet below the Encrinal limestone. Other specimens in a crushed condition, and showing the rapid tapering of this species occur in the Strophalosia bed about fifty feet below the Encrinal limestone. No siphuncle has been observed in these specimens. The distance between the sutures is about 3 mm.

10. ORTHOCERAS NUNTIUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 299, pls. 43, 82.

This species is represented by a number of fragments from the Trilobite beds. In the majority of specimens the shell is preserved, showing the fine longitudinal striæ. The species appears to be characteristic of these beds occurring in them wherever they are exposed. A single fragment has been found outside of the Trilobite beds. This was obtained in the shale two to four feet below the lowest Trilobite bed at Avery's creek.

11. ORTHOCERAS TELAMON, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 291, pl. 85.

A few fragments from the Encrinal limestone are referred to this species. The septa are distant 5 mm. where the diameter of the shell is 11 mm.

12. ORTHOCERAS EXILE, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 290, pl. 39, 84, 85.

In the Strophalosia bed occur a number of compressed specimens showing the constriction of the living chamber and other characters of this species. The living chamber is usually uncompressed. The distance between the sutures varies from 3 to 5 mm. No siphuncle has been observed. A small flattened fragment from Idlewood ravine (twenty-five feet below the Encrinal limestone) is, with some doubt, referred to this species, A similar fragment from twelve feet below the Encrinal limestone may be of the same species.

PTEROPODA.

Genus **Tentaculites**, Schlotheim.

13. TENTACULITES BELLULUS, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 169, pl, 31, 31*a*.

I have found this species as low as fourteen feet below the Encrinal limestone. It usually occurs as isolated individuals, though a fragment of shale containing four individuals was found in the *Stropheodonta demissa* bed. None of the specimens show the apex, but all show the annulations and the concentric striae. The length of the largest specimen is about 17 mm. An impression in shale from the upper part of the Moscow beds is doubtfully referred to this species.

14. TENTACULITES GRACILISTRIATUS, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 173, pl. 31, 31*a*.

In 1879, Professor Hall wrote; * "the latter form [*T. gracilistriatus*] is at present unknown in the centre of the Hamilton group or in any higher position; the *Styliola* [*Styliolina*] alone so far as known being present in the superior strata." In 1885, J. M. Clarke† described this species from the Genesee and Naples shales of Ontario county, N. Y., where it is associated with *Styliolina fissurella*.

I have found several specimens in the Stropheodonta demissa bed, also a large number in the upper part of the Moscow shales. At Section F, Eighteen-mile creek, about two feet below the Styliolina band, occurs a thin layer of shale, less than half an inch in thickness, in which this little shell occurs to the exclusion of almost every other form. No Styliolinas have been observed, though in the lower beds the two are associated. The specimens are usually found crushed and may at first be taken for *Styliolina fissurella*. The annulations however are shown on all the specimens, but the longitudinal striae do not always appear. The species also occurs in the shale four feet below the Encrinal limestone at Section C, where it is associated with *S. fissurella*. I have found it as low as the Trilobite beds, where it is rare and associated with the species next enumerated. It does not occur again until we reach the Marcellus shale in the upper beds of which it is a common form.

* Pal. N. Y. vol. 5. pt. 2, p. 177.
† Bull. U. S. Geol. Surv. No. 16.

Genus **Styliolina**, Karpinsky.

15. STYLIOLINA FISSURELLA, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 178, pl. 31*a*.

This little shell is everywhere abundant in the Hamilton group. Found in the lowest exposed layers, into which it passes from the underlying Marcellus shale, it continues through the Hamilton beds, and into the overlying Genesee and Naples beds. One can scarcely examine the shale anywhere without finding some traces of this pteropod. Some thin layers of the shale seem to be completely filled with these shells, though nowhere in the Hamilton group of this region is the accumulation sufficient to form bands of limestone as is the case in the Genesee shale. Frequently the shells are found arranged in bands or streaks along the bedding plane, as if they had been suddenly overwhelmed. The shells are all small, and usually crushed, showing the line of fracture, or the "fissure" along the center. No specimens of this species have been observed in the Encrinal limestone.

Genus **Coleolus**, Hall.

16. COLEOLUS (?) GRACILIS, Hall.

1879, Pal. N. Y., vol. 5, pt. 2, p. 190, pl. 32*a*.

A specimen embedded in shale, and agreeing with the figure and description of the Chemung species was obtained from the *Stropheodonta demissa* bed.

17. COLEOLUS TENUICINCTUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 185, pl. 32, 32*a*.

This species occurs in the Nautilus bed on the lake shore. It is a rare form, and has not been observed above this horizon.

GASTEROPODA.

Genus **Platyceras**, Conrad

18. PLATYCERAS ERECTUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 5, pl. 2.

A number of small specimens from the *Stropheodonta demissa* bed are referred to this species. The specimens present the smooth character and close coiling of this species and are probably to be regarded as immature individuals.

19. PLATYCERAS CARINATUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 5, pl. 2.

This species occurs in the *S. demissa* bed and in the Encrinal limestone. Specimens of various sizes were obtained, most of them not in a good state of preservation. It is not an abundant form.

20. PLATYCERAS THETIS, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 8, pl. 3.

Several good specimens of this species were found in the *S. demissa* bed. The species also occurs in the middle Pleurodictyum layer of Avery's creek.

21. PLATYCERAS BUCCULENTUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 10, pl. 3.

A specimen from the Encrinal limestone is, with some doubt, referred to this species.

22. PLATYCERAS SYMMETRICUM, Hall.

1879, Hall, Pal. N. Y. vol. 5, pt. 2 p. 9, pl. 3.

This species is rare. A single small individual was found in the middle Pleurodictyum layer of Avery's creek.

23. PLATYCERAS (ORTHONYCHIA) ATTENUATUM, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2 p. 6, pl. 3.

This species occurs in the Encrinal limestone, and in the *S. demissa* bed. It is found with the apex variously coiled, but expanding regularly and rapidly towards the aperture. The specimens are usually more or less crushed. A single crushed specimen from the Trilobite beds probably belongs to this species.

Besides the above, a number of small unidentified specimens of *Platyceras* occur in the uppermost one foot of the Hamilton shales and in the Encrinal limestone. They are usually quite perfect, but on account of their small size cannot readily be referred to any of the described species.

Genus **Platyostoma**, Conrad.

= **Diaphorostoma**, P. Fischer.

24. PLATYOSTOMA (DIAPHOROSTOMA) LINEATUM, Conrad.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 21, pl. 10.

1885, Paul Fischer, Manuel de Conchyliologie, p. 756.

This is the most abundant gasteropod in the Hamilton group of this region. It is comparatively rare in the shales and limestones between the Trilobite beds and the Strophalosia bed, and has not been observed below the latter. A single small but perfect specimen was found in the lowest Trilobite bed. It is abundant in the uppermost one foot of the Hamilton shales, but all the specimens are small. It is fairly abundant in the Encrinal limestone, and is also the best preserved gasteropod of that rock. It occurs sparingly in the lower Moscow shales. The specimens from the limestone are all very much larger than the shale specimens, these latter being all undersized. The surface markings are usually obliterated in the limestone specimens but show beautifully in most of the specimens from the shale.

Genus **Euomphalus**, Sowerby.

25. EUOMPHALUS (PHANEROTINUS) LAXUS, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 60, pl. 16.

A fragment showing the circular tube, gradual enlargement, and loose coiling of this species was found in the Encrinal limestone. It has not been found in the shales above or below, but occurs in the upper layers of the Marcellus shale, and in the lower portion of the transition beds.

26. EUOMPHALUS (STRAPAROLLUS) RUDIS, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 58, pl. 16.

A closely coiled specimen with the shell removed, was found in the Encrinal limestone.

Genus **Pleurotomaria**, Defrance.

27. PLEUROTOMARIA LUCINA, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 67, pl. 18.

Several casts from the Encrinal limestone are referred to this species. They show the flattened revolving band characteristic of this form.

28. PLEUROTOMARIA LUCINA, var. PERFASCIATA, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 83, pl. 21.

A single fragment showing the form and surface markings of this variety was found in the middle Pleurodictyum layer at Avery's creek.

29. PLEUROTOMARIA ITYS, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 76, pl. 20.

This species occurs in the Pleurodictyum beds, but is rare, being chiefly represented by casts. In the Nautilus bed occurs a variety which approaches *P. itys*, var. *tenuispira*, in having six volutions, strong revolving striæ, and coarse crenulations. The medial band however is bounded by strong revolving carinæ, as in the typical forms of the species.

30. PLEUROTOMARIA CAPILLARIA, Conrad.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 77, pl. 20.

A number of crushed specimens from the Strophalosia bed along the lake shore, present the features of this species, especially in the revolving carinæ.

Genus **Loxonema**, Philips.

31. LOXONEMA HAMILTONIÆ, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 45, pl. 13.

This species occurs only in the Strophalosia bed. It is a common form and usually shows the surface striæ. It is often loosely coiled.

32. LOXONEMA DELPHICOLA, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 47, pl. 13.

This species, like the preceding, is restricted to the Strophalosia bed. The specimens are all crushed, but show the suture band, and there is little doubt of their identity.

Genus **Bellerophon**, Montfort.

33. BELLEROPHON LEDA, Hall.

1879, Hall, Pal. N. Y., vol. 5, pt. 2, p. 110, pl. 23.

I have found this species only below the Trilobite beds. It occurs sparingly in the shale below them and in the Pleurodictyum beds. In the Strophalosia bed it is a common form, being well preserved and of good

size. It is extremely rare below this limestone, a few crushed specimens only having been found in the shale about twenty feet below the Strophalosia bed. The species may be regarded as practically restricted to the Strophalosia bed, characterizing it wherever exposed.

LAMELLIBRANCHIATA.

Genus **Aviculopecten**, McCoy.

34. AVICULOPECTEN PRINCEPS, Conrad.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 1, pls. 1, 5, 6, 24, 81.

This species occurs in the Trilobite beds, and rarely in the shale immediately below. A small left valve from the Trilobite beds measured: length, 33 mm., height, 30 mm., length of hinge, 26 mm. A larger specimen from these beds on the lake shore measures: length, 59 mm., height, 55 mm., length of hinge, about 35 mm. In the shales above these beds fragments of both valves occasionally occur. Similarly in the *S. demissa* bed, a number of fragments, as well as perfect valves were obtained. A specimen of a right valve measured 36 mm. in height, with length and hinge nearly the same. A few specimens, chiefly internal moulds, were obtained from the Encrinal limestone.

35. AVICULOPECTEN EXACUTUS, Hall.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 8, pl. 3.

This species is rare and represented by fragments obtained from the shale down to seventeen feet below the Encrinal limestone. In the S. demissa bed it is more abundant and a number of impressions and internal moulds were obtained, the shell being only rarely preserved. The usual size of the specimens is below the average for the species.

Genus **Pterinopecten**, Hall.

36. PTERINOPECTEN CONSPECTUS, Hall.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 66, pl. 17.

This species is comparatively rare in these shales, the specimens obtained being mainly fragments and impressions. A specimen was obtained from the upper Pleurodictyum bed at Avery's creek. I have found it as low as seventeen feet below the Encrinal limestone at Eighteen-mile creek, and from the shales between this point and the *S. demissa* bed several fragments and impressions were obtained. In the latter bed it is somewhat more abundant

though perfect specimens are seldom obtained. The specimens show considerable variation, both in outline and surface markings, approaching on the one hand, *P. Hermes*, and on the other, *P. intermedius*. While the surface markings vary greatly, all the specimens show the heavy, distant striae. The intermediate striae are often numerous and fine, at other times few, and nearly equal to the larger ones. The coarser concentric striae usually interrupt the continuity of the rays, the continuation below being often shifted to one side or the other. A specimen from the *S. demissa* bed has the characteristic outline of *P. Hermes* but the striae are interrupted as in specimens of *P. conspectus*. I regard this, however, as a variety of *P. conspectus* which points to an intimate relation between the two species of this genus.

A single fragment of a left valve showing the form and simple ligamental groove of this species, was obtained from the lower five feet of the Moscow shales. The specimen is embedded in the rock, and the beak and anterior ear are broken away. The interior is perfectly smooth, showing no trace of rays; a condition of preservation unusual in this shell, where the interior shows the rays almost as well as the exterior. On moistening the interior, the rays may be faintly seen through the shell, the concentric striae also becoming apparent.

37. PTERINOPECTEN HERMES, Hall.

1884, Hall, Pal. N. Y. vol., 5, pt. 1, p. 64, pl. 17.

In the calcareo-argillaceous layer four feet below the base of the Trilobite beds at Avery's creek occur a few specimens having the normal characteristics of this species.

38. PTERINOPECTEN UNDOSUS, Hall.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 72, pl. 2, 82.

A number of specimens with the test removed are provisionally referred to this species. They show the surface markings and the concentric wrinkles, as well as the deep byssal notch in the right valve, features which characterize this species. The form of the shell and ears, however, differs from the typical form. More material is required to make an accurate determination. The specimens are all from the *S. demissa* bed.

39. PTERINOPECTEN, sp.

A small specimen retaining both valves, and differing from any of the characteristic forms of these shales was found in the *S. demissa* bed. It may prove to be the young of *P. vertumnus*.

Genus **Pterinea**, Goldfuss.

40. PTERINEA FLABELLA, Conrad.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 93, pl. 14, 15, 83.

This species is common in the *S. demissa* beds, where it preserves its surface markings to a considerable extent. The shell is thin and fragile, never attaining the thickness which this species presents in the eastern part of the state, where the shales are more arenaceous. The specimens are also usually smaller than the average size. Several specimens obtained are very oblique, almost resembling in this respect the next species enumerated; the surface markings, however, are typical. It is not an uncommon form, in the shale immediately above the *S. demissa* bed (Stictopora bed). Several fragments were obtained from the shale down to twelve feet below the Encrinal limestone. The species however is practically restricted to the upper one foot of the Hamilton shales.

Genus **Actinopteria**, Hall.

41. ACTINOPTERIA DECUSSATA, Hall.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 111, pls, 17, 18, 20, 84.

This is not an uncommon form in the Encrinal limestone, where the specimens are often large. Though often somewhat effaced, the characteristic surface markings can usually be made out. Fragments of this species also occur in the upper foot of the Hamilton shale beneath the Encrinal limestone, while occasional representatives of the species are found in the Pleurodictyum beds of Avery's creek and the lake shore. The intermediate shales have not furnished any specimens, nor have any been found above the Encrinal limestone.

42. ACTINOPTERIA BOYDI, Hall.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 113, pls. 19, 84.

This species is rare in our district. A few specimens were found in the Pleurodictyum layers of Avery's creek and the lake shore.

Genus **Leiopteria**, Hall.

43. LEIOPTERIA RAFINESQUEI, Hall.

1884, Hall, Pal. N. Y., vol. 5, pt. 1, p. 161, pl. 15, 20, 88.

This species is represented by a single left valve, rather imperfect, but showing the characteristic form and surface markings. It was found in the *S. demissa* bed.

44. LEIOPTERIA, sp.

A small left valve, which cannot satisfactorily be referred to any of the described species was obtained from the *S. demissa* bed.

Genus **Plethomytilus**, Hall.

45. PLETHOMYTILUS OVIFORMIS, Conrad.

1884, Hall, Pal. N. Y., vol. 5. pt. 1, p. 255, pl. 31, 87.

This species is quite common in the upper part of the Encrinal limestone at Section D, Eighteen-mile creek. The specimens obtained are all in the form of internal moulds, from which the shell has been dissolved. Rarely a trace of the shell remains, showing the concentric lines of growth and the coarser elevated lines. The shells seem to have been entirely filled with the fine fragments of other organisms, and these stand out in relief on the weathered portions of the specimens. The specimens are large and usually occur with the valves separated and weathered out on the exposed upper portion of the limestone. They are especially abundant near the lower end of the section. A single specimen was obtained with the two valves in conjunction.

The dimensions of this specimen are 80 by 55 mm., with a depth between the two valves of 47 mm. Although this species is fairly common in the upper part of the limestone, and specimens appear to lie on the very top of the rock, no specimen has as yet been found in the Moscow shales, nor have any been obtained from the Lower shales. The species also seems to have been restricted to the upper portion of the limestone. Its horizontal distribution in the limestone is likewise very much restricted.

Genus **Modiomorpha**, Hall.

46. MODIOMORPHA CONCENTRICA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 275, pl. 34, 35, 36.

This is a common form in the Encrinal limestone of Section D. The specimens usually have the shell removed, but the concentric striae nevertheless show well. The specimens occur usually as imperfect separate valves. A few specimens only, and these in a poor state of preservation, have been found outside of the limestone. These were obtained from the Pleurodictyum and other calcareous beds between the Trilobite and Strophalosia beds of the lake shore and Avery's creek.

47. MODIOMORPHA SUBALATA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1. p. 283, pls. 35, 39.

This is the most abundant lamellibranch in these shales, being at the same time one of the best preserved. It is very common in the limestone layer which has been named from it the *Modiomorpha sublata bed,* and which is twenty-five feet below the Encrinal limestone. The specimens are of average dimensions and though mostly denuded of the shell, show the surface markings. It is common in the Trilobite beds, but otherwise it is not abundant. A few fragments and valves have been found up to ten feet below the Encrinal limestone. A doubtful specimen was obtained at Section C, about three feet below the Encrinal limestone. It occurs occasionally in the upper Pleurodictyum layer of Avery's creek and rarely in the shale immediately above.

48. MODIOMORPHA ALTA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 278, pl, 37, 80.

A single specimen denuded of the test, but having the proportions of this species, was found in the middle Pleurodictyum layer at Avery's creek. The dimensions are: length 68 mm.; greatest height 43 mm.

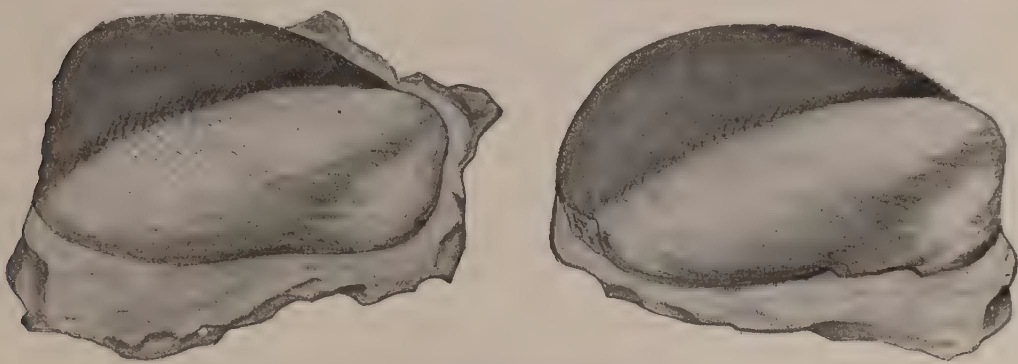
Genus **Goniophora**, Phillips.

49. GONIOPHORA MODIOMORPHOIDES, sp. nov.

Description. Shell of medium size or larger; length one and a half times the height. Ventral margin nearly straight for about two-thirds of the distance from the anterior end, with a slight constriction at about the anterior third delimited by the oblique sinus. Posterior portion gently deflected upwards, to the umbonal ridge. Cardinal line arcuate, extending for about three-fourths of the length of the shell; margins inflected. Posterior end obliquely truncate, margin sometimes slightly curving.

Valves more or less convex below the umbonal ridge, rarely almost flat; a slight concavity just beneath the ridge, sometimes observed. Above the ridge, the slope to the cardinal line is flat or slightly concave. Beaks nearly anterior, incurved, not shown in the typical specimens. Umbonal ridge angular, extending from the beak to the post-inferior margin, regularly and evenly arcuate in the posterior two-thirds of its extent, more abruptly bent downwards in the anterior third. The cardinal region above the ridge

is uniformly arcuate in various degrees from beak to posterior margin, the amount of arcuation depending on the point of measurement. Anterior end small, scarcely extending beyond the beak, rounded, separated from the rest



FIGS. 1, 2. Goniophora modiomorphoides, sp. n.

of the shell by a well-marked oblique sinus which extends from the beak to the ventral margin where it causes a constriction in the margin.

Test ornamented by numerous strong, regular, subimbricating lines of growth, which are abruptly deflected at the umbonal slope, continuing at a slightly acute angle, and becoming more curving towards the cardinal margin.

Anterior muscular impression subcircular, pronounced. Other internal characters not observed. Three specimens of the ordinary size measure: 62, 57, and 53 mm. in length, by 37, 36, and 34 mm. in height. A small specimen measures 41 mm. in length by 24.5 mm. in height.

This species differs conspicuously from all the other Hamilton species in its regularly arcuate umbonal ridge. In general appearance it recalls the form of some of the common species of *Modiomorpha*, especially *M. concentrica*, which it resembles in the regular striae, the anterior subnasute end, the well-marked sinus, and the arcuate umbonal ridge. The angularity and distinctness of this ridge in the present species distinguish it at once. The specific name is intended to express this similarity.

The type specimens were obtained from the upper part of the Encrinal limestone, where they are associated with *Modiomorpha concentrica* and other species. In the limestone specimens, the test is seldom well preserved, and its thickness cannot be ascertained. A specimen in shale from the lake shore is referred to this species. Two specimens from the Encrinal limestone show a greater angularity in the umbonal ridge which is almost crested. The posterior slope is more oblique and more direct.

Genus **Cypricardella**, Hall.

50. CYPRICARDELLA BELLISTRIATUS, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 308, pls. 42, 73, 74.

This species occurs mostly as impressions on shale, or as imperfect valves with the shell removed. Some fragments were found in the Idlewood ravine about twenty-five feet below the Encrinal limestone, and others at Section B, nine to twelve feet below the Encrinal limestone. An internal mould from the Encrinal limestone, probably represents the short form of this species. This species occurs sparingly in the Pleurodictyum beds and more rarely in the shale above. A specimen from the Strophalosia bed belongs to this species.

Genus **Nuculites**, Conrad.

51. NUCULITES OBLONGATUS, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 324, pl. 47.

A single specimen of this species was found at Section C, four feet below the Encrinal limestone. It is the internal mould of a left valve, with the impression of the internal ridge well marked. The umbonal ridge is somewhat more angular than in the typical forms. The length of the specimen is 15 mm., its height 6.5 mm. Several other specimens in the same condition of preservation were found in the Strophalosia bed on the lake shore.

52. NUCULITES NYSSA, Hall.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 328, pl. 47.

This species, originally described from concretionary layers in the shales of the Hamilton group on the shore of lake Erie, has come under my observation only in the Strophalosia bed, where the specimens usually have the shell denuded. It is not a common form.

53. NUCULITES TRIQUETER, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 326, pls. 47, 93.

This species occurs only in the transition shales and in the Marcellus shales on the lake shore. It is a rare form.

Genus **Palæoneilo**, Hall.

54. PALÆONEILO CONSTRICTA, Conrad

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 333, pls. 48, 51.

This species occurs in the Lower shales, where I have found it at a depth of twenty and forty-five feet below the Encrinal limestone. It is a rare form, only four specimens having been found in all. I have not found it above the *S. demissa* bed. The following are the measurements of three of the specimens: length, 15, 14, and 14 mm. respectively; height, 7, 9, and 10 mm. respectively, showing thus some variation in the proportion of length to height.

55. PALÆONEILO TENUISTRIATA, Hall.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 336, pl. 49, 93.

This species is common in the lower portion of the Moscow shales, where specimens in a good state of preservation may be obtained. It is most abundant in the layers between two and three feet above the Encrinal limestone, a single specimen only having been found in the lowest two feet. The species has not been found above the lower three feet of Moscow shale, but below the Encrinal limestone it occurs sparingly down to the base of the Hamilton shales. A few doubtful specimens were obtained from the Strophalosia bed. The specimens from the Lower shales are never so well preserved as are those from the Moscow shales, while at the same time the depression of the umbonal ridge is more marked, and the specimens rather larger than the usual size. The depression of the umbonal ridge is but slightly marked in the specimens from the Moscow shales, the posterior margin occasionally appearing regularly rounded. In some specimens the surface striæ become so coarse that it is difficult to distinguish them from the next species.

56. PALÆONEILO FECUNDA, Hall.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 336, pl. 49.

This species was found associated with the preceding in almost all the strata. It is less abundant than *P. tenuistriata* in the Moscow shales, but more common and better preserved than that species in the Lower shales. I have not found it lower than twenty-one feet below the Encrinal limestone. A small specimen measures: length 13 mm. height 8 mm.

57. PALÆONEILO MUTA, Hall.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 337, pl. 49.

This pretty little species has a vertical distribution similar to the preceding, but it is somewhat more abundant in the lowest two feet of the Moscow shales. It has been found as low as the Strophalosia bed, but in this, as well as in the shales above, it is extremely rare.

58. PALÆONEILO EMARGINATA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 338, pl. 50.

This is a common shell in the Hamilton (Lower) shales of this region, being scattered through the upper twenty-five feet of the shales. The specimens are usually smaller than those from more eastern localities, but they are otherwise well developed. The largest specimen found measured 25 mm. in length, by 12 mm. in height.

Genus **Macrodon**, Lycett.

59. MACRODON HAMILTONIÆ, Hall.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 349, pl. 51.

A single specimen, the posterior half of a right valve, was found in the Hamilton shales. The specimen shows the form, and the characteristic interrupted radii, thickened at their lower ends, and separated by the concentric varices. The specimen comes from about ten feet below the Encrinal limestone at Section B.

Genus **Grammysia**, De Verneuil.

60. GRAMMYSIA, sp.

A fragment, probably of *G. arcuata* was found at Section B, about ten feet below the Encrinal limestone. It shows the surface markings of that species. (See Pal. N. Y., vol. 5, pt. 1, p. 373.)

61. GRAMMYSIA, sp.

A fragment resembling fig. 3, pl. 56, vol. 5, pt. 1, Pal. N. Y., was found at Section B, fourteen to seventeen feet below the Encrinal limestone.

Genus **Sphenotus**, Hall.

62. SPHENOTUS TRUNCATUS, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 394, pl. 65.

A small right valve, having the form and markings of this species was obtained from the *S. demissa* bed. The dimensions are: length 9 mm., height 4.5 mm.

Genus **Conocardium**, Bronn.

63. CONOCARDIUM, sp.

Two or three species of *Conocardium* occur in the upper Encrinal limestone. The material obtained is so crushed and broken, and the shell so frequently dissolved, that it is impossible to make specific determinations.*

Genus **Lunulicardium**, Münster.

64. LUNULICARDIUM FRAGILE, Hall.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 434, pl. 71.

A single left valve of this species was found in the Hamilton shales about ten feet below the Encrinal limestone (Section B). The greater portion of the test is gone, but the remaining portion shows the fine concentric striæ. The cast shows faint radiating striations. The dimensions of the specimen are: height, 11 mm., length, 9.75 mm. This species, though extremely rare in the typical Hamilton shales, is not of uncommon occurrence in the transition shales, and becomes progressively more abundant as we approach the Marcellus shales.

Genus **Pholadella**, Hall.

65. PHOLADELLA RADIATA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 469, pl. 78, 96.

This species was described as occurring in some concretionary layers at Eighteen-mile creek. I have found it in the *Modiomorpha subalata bed*, and in the shale about ten feet below the Encrinal limestone (Section B).

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*More recent study has shown the presence of *C normale*, Hall, and *C eboraceum*, Hall, among the fragments collected from the Encrinal limestone.

Genus **Cypricardinia**, Hall.

66. CYPRICARDINIA INDENTA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 485, pl. 79, 96.

This is one of the most abundant species of lamellibranchs in the upper part of the Hamilton shales. It is extremely abundant in the upper part of the shale, but rare below. Two specimens were found between two and three feet below the Encrinal limestone, but none between this and the Trilobite beds. Below the latter it is not an uncommon form down to the Nautilus bed. The specimens are usually well preserved, in many instances retaining the shell entire, and showing the two sets of striae. The specimens on the whole are smaller than the average as given by Professor Hall. Five measurements resulted as follows: length, 6, 5, 7, 12, 12.5, 17.5 mm.; height, 4, 4.2, 6.8, 6, 10 mm. It will thus be seen that there is some variation in the proportion of length to height. A single specimen, probably from the lower two feet of the Moscow shales, belongs here, but the exact position of the fossil is somewhat doubtful. It is the only one found in the Moscow shales.

Genus **Modiella**, Hall.

67. MODIELLA PYGMÆA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 514, pl. 76.

A single small left valve from Idlewood ravine twenty-five feet below the Encrinal limestone, is of this species. The specimen is denuded of the test, but the radiating striæ are faintly indicated on the cast. The form and proportions are those of the typical individuals from the center of the state. A few small specimens, chiefly casts from the Strophalosia bed, are referred to this species.

Genus **Tellinopsis**, Hall.

68. TELLINOPSIS SUBEMARGINATA, Conrad.

1885, Hall, Pal. N. Y., vol. 5, pt. 1. p. 464, pl. 76.

Of this well marked species a single specimen was found in the Strophalosia bed. The test is dissolved and no radii are shown, but the identity of the specimen is beyond doubt.

Genus **Glyptocardia**, Hall.

69. GLYPTOCARDIA SPECIOSA, Hall.

= *Cardiola retrostriata*, Von Buch.

1885, Hall, Pal. N. Y., vol. 5, pt. 1, p. 426, pl. 70, 80.

A fragment of the left valve of this strongly marked species was found in the Strophalosia bed. The height of the specimen is 10 mm. and the surface characters are well preserved.

BRACHIOPODA.

Genus **Lingula**, Bruguiere.

70. LINGULA LEANA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 9, pl. 2.

This species occurs in the Lower shales where I have found specimens at a depth below the Encrinal, ranging from eight to fourteen feet. A single specimen has been obtained as low as twenty feet at Section B. The specimens are usually much flattened, and seldom show the faint radiating striæ. Two specimens from a depth of nine feet measured: length, 12 and 13 mm.; width 9 and 10 mm. respectively.

71. LINGULA DELIA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 12, pl. 2.

The few specimens obtained show the usual outline and size of this species, together with the mark of the median septum, characteristic of the brachial(?) valve. The species occurs below the Encrinal limestone.

72. LINGULA SPATULATA, Vanuxem.

1867, Hall, Pal. N. Y., vol. 4, p. 13, pl. 1.

At Section B, at a depth of from twelve to fourteen feet below the Encrinal limestone, I found six specimens which show the characteristics of this species. Another specimen was found in the *S. demissa* bed. The sides of these specimens regularly curve to the beak, and the front is evenly rounded. The specimens are rather more convex than the ordinary forms from the Genesee beds, and the slope of the sides is consequently a more abrupt one. The surface is gently arcuate from beak to base, and near the beak the slope of the lateral margin is somewhat more abrupt. Concentric

striae, and a few obscure radiating lines are usually visible. Two specimens measure 6 and 5.5 mm. in height by 3.5 and 3 mm. in width respectively. The specimens are slightly larger and somewhat more convex than the prevailing form. The beaks are likewise less attenuated. Nevertheless I can regard this simply as a variety of this species.

73. LINGULA, sp.

In the *S. demissa* bed was found a fragment of a valve having a nearly straight front, somewhat lamellose lines of growth, and distinct radiating striae. The specimen is of medium size.

Genus **Orbiculoidea**, D'Orbigny.

74. ORBICULOIDEA MEDIA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 20, pl. 2.

1892, J. Hall and J. M. Clarke, Pal. N. Y. vol. 8, pt. 1, p. 120.

This species is not uncommon in these rocks. It usually occurs in clusters and seems to be confined to distinct layers. Specimens were obtained about ten feet below the Encrinal limestone, and in the middle and upper Moscow shales. A large distorted specimen from Section B., fourteen to seventeen feet below the Encrinal limestone, belongs to this species.

75. ORBICULOIDEA DORIA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 19, pl. 2.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 120.

A few specimens which resemble this species, but are not attached to other fossils, were found in the Moscow shale associated with *O. media* (*O. media bed.*)

76. ORBICULOIDEA LODENSIS, Vanuxem.

1867, Hall, Pal. N. Y., vol. 4, p. 22, pl. 2.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 120.

In the *S. demissa* bed were found small brachial valves. Fine concentric striae are visible on the specimens, and faint radiating lines appear on all parts of the shell. From slight exfoliation, the long, narrow, slit-like depression on the anterior slope of the beak has become visible in the brachial valve. (See Pal. N. Y. vol. 4, pl. 1, fig. 14 e.) This depression extends about one-third the distance from the beak to the anterior margin. The

ante-posterior diameter of the shell is 6 mm.; the transverse diameter, 5 mm.; distance from beak to posterior margin, 2.2 mm. Several specimens of *Orbiculoidea* have been found in the Nautilus bed. These show radiating folds on all parts of the shell, and probably represent a variety of this species.

Genus **Schizobolus,** Ulrich.

77. SCHIZOBOLUS TRUNCATUS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 23, pl. 1, 2.

1892, J. Hall, and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 87, pl 3.

This species has, so far as I am aware, heretofore been reported only from the Genesee and overlying beds. It occurs here, however, quite abundantly in the upper part of the Moscow shale, where its downward limit is usually marked by a layer of calcareous concretions. The lowest position in which it has been found is in the middle Moscow (*Orbiculoidea media bed*) of Section E, where a few specimens occur with *O. media.* It occurs again in this shale, three feet below the Styliola limestone. The specimens found here are slightly larger than the usual size. The average of six measurements of specimens of the ordinary form are: length, 6.2 mm.; width, 5.7 mm. Whenever the specimens occur in the limestone layer, as at Section H, they are more or less exfoliated. Nevertheless a number of specimens show the median septum in the interior of the brachial valve, while the central muscular scars were likewise observed in a number of specimens. These features are less perfectly shown in the specimens from the shale. The majority of the specimens found are brachial valves.

Genus **Craniella,** Œhlert.

78. CRANIELLA HAMILTONIÆ, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 27, pl. 3.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 153.

This species is rather rare in the shales of Eighteen-mile creek, the few specimens found being usually in a poorly preserved condition. It occurs mainly in the upper part of the Hamilton shales, but several specimens were found in the shale two feet below the base of the Trilobite beds at Avery's creek.

Genus **Pholidops**, Hall.

79. PHOLIDOPS HAMILTONIÆ, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 32, pl. 3.

This is a common form, extending through the greater part of the group. The valves have not been found in conjunction, but single valves are common. The internal and external moulds in many cases alone represent these shells.

The lowest position in which this species has been observed in the Hamilton shales, is about forty feet below the Encrinal limestone. It is rare at this level, nor is it very abundant in the next twenty-five feet of the shales. Above this it becomes more frequent until about ten feet below the Encrinal limestone it is a common fossil, occurring both as shells and impressions. Above this it becomes again comparatively infrequent, being only an occasional constituent of the faunas for the remainder of the Hamilton shales. No specimens have been found in the Encrinal limestone. In the Moscow shales immediately above, it is quite abundant, but after two or three feet, it becomes rare again, and has not been found anywhere in the upper part of these shales.

80. PHOLIDOPS LINGULOIDES, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 414, pl. 3.

(See also vol. 8, pt. 1, pl. 4*i*.)

This species occurs in the Encrinal limestone and in the *S. demissa* bed. A single separate valve from the limestone allows accurate measurements. Besides this, attached specimens in both shale and limestone were found. In the perfect valve found the beak projects .6 mm. beyond the posterior border of the shell, the total length of the shell being 7 mm., and its width 5.2 mm. The "area" thus formed is arcuate and striated transversely by the lines of growth. A specimen adhering to the interior of a *Stropheodonta* shows coarse lamellose lines of growth. This specimen measures 7.7 mm. in ante-posterior diameter, and 6.9 mm. in transverse diameter. The shell is much thicker than that of *P. Hamiltoniæ*.

81. PHOLIDOPS OBLATA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 414, pl. 3.

(Also vol. 8, pt. 1, pl. 4*i*)

Several specimens of *Pholidops* from the Encrinal limestone are referred to this species. The specimens are broader at the posterior end, which is

broadly and evenly rounded. The beak is elevated, and distant from the posterior border less than one-fourth the length of the shell. Margins of the valves flattened. The valves are very convex, and the posterior slope is very abrupt in the latter half of the distance from the beak.

The surface in all the specimens is exfoliated, but fine concentric striae are visible. Two specimens measure in ante-posterior diameter, 7 mm. and 6.5 mm., and in transverse diameter 6.6 mm. and 6.3 mm., respectively. The usual size of *P. Hamiltoniæ* is 4 by 3 mm. a difference in size and proportions being thus indicated between the two species.

The original description was from an impression of an interior of larger size, and I am not aware that the exterior has heretofore been described. Should the present specimens prove to be of this species, they will add to the characters differentiating it from the other species of this group.

The specimens are associated with *P. linguloides*, and the possibility that they represent the other valve of a very inequivalve form of which *P. linguloides* is a part, should not be overlooked. (See Pal. N. Y., vol. viii, pt. 1, pl. iv *i*, expl. fig. 36.)

Genus **Rhipidomella**, Œhlert.

82. RHIPIDOMELLA VANUXEMI, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 47, pl. 6.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 208, pl. 6*a*.

This, the most abundant and characteristic species of *Orthis* in the Hamilton group, occurs throughout the Lower shales and in the Encrinal limestone, but is rather rare in the Moscow shales, and entirely wanting in the upper portion of the strata. It is likewise rare in the lower portion of the Hamilton shale, though specimens have been found as low as the Pleurodictyum beds. It becomes more abundant as we pass upward until a few inches below the Encrinal limestone it is one of the most abundant fossils, though most of the specimens found are small. It is abundant in the Encrinal limestone, where the specimens are of average size and larger. The species continues upwards into the Moscow shales for about five feet, after which it seems to have disappeared from this region. The specimens from the Moscow shales are of average size.

83. RHIPIDOMELLA LEUCOSIA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 48, pl. 7.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 208, pl. 6*a*.

This species occurs in the Encrinal limestone, where it is associated with the preceding one. It also occurs in the shale below the Trilobite layers. The specimens from the limestone are all very much exfoliated, and show the surface features poorly; the form and convexity being the only characters indicating their identity. Those from the shales however are well preserved, and show the characters of typical forms of this species.

84. RHIPIDOMELLA PENELOPE, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 50, pl. 6.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 208, pl. 6*a*.

This species is common only in the Encrinal limestone, where the shells attained their full size. The specimens obtained, though mostly exfoliated, show the characteristic form, surface markings, and in some cases the muscular impressions. It is, however, not so abundant as *R. Vanuxemi.* A number of young individuals, apparently of this species, were obtained from the shale beneath the limestone. A few large and well-developed specimens were found in the two feet of shale below the Trilobite beds of Avery's creek.

85. RHIPIDOMELLA IDONEUS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 52, pl. 7.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, p. 208.

A few specimens of this species were found in the Encrinal limestone and one in the lower Moscow shales three to five feet above the Encrinal limestone.

86. RHIPIDOMELLA CYCLAS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 52, pl. 7.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 208.

A single individual of this species was obtained from the two feet of shales below the Trilobite beds of Avery's creek.

Genus **Orthothetes**, Fischer de Waldheim.

87. ORTHOTHETES ARCTOSTRIATA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 71, pl. 9.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 253.

This species occurs throughout the greater part of the group, though it is sparingly represented except at certain levels. It occurs at intervals and rarely in the transition shales on the lake shore, and is not uncommon in the beds above the Strophalosia bed, and up to the Trilobite beds. In the latter several specimens were found, and others above this, at various intervals, to the Encrinal limestone. I have not observed it in that rock, but it occurs sparingly above it, several specimens having been found near the top of the Moscow shales. It is abundant between one and three feet, and between seven and twelve feet below the Encrinal limestone. Specimens occur with the hinge approaching that of the next species, and the striae occasionally approximate to those of the same form.

88. ORTHOTHETES PERVERSA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 72, pl. 9.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 253.

This species is rare at Eighteen-mile creek. I have found only a few specimens which I can satisfactorily refer to this species. These came from the *S. demissa* bed of Section D. The species occurs sparingly in the Pleurodictyum beds of Avery's creek.

Genus **Stropheodonta**, Hall.

89. STROPHEODONTA DEMISSA, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 101, pl. 17.

(See also vol. 8, pt. 1.)

This species is, with few exceptions, restricted to about six inches of shale in the upper foot of the Hamilton shales, the great majority of specimens occurring from ten to twelve inches below the Encrinal limestone. (*S. demissa* bed). The specimens are large and well formed, and occur abundantly within this horizon. Two specimens only were found as low as eighteen inches below the Encrinal limestone. A small brachial valve was found about six inches below the Encrinal limestone, while in that rock only one specimen

was found. The extremely limited vertical distribution of this important species is remarkable, and accords well with what has been observed elsewhere. In the Livonia salt shaft section (13th Annual Rept. N. Y. State, Geol. Vol. 1, p. 145) it is recorded from the Encrinal limestone only

90. STROPHEODONTA CONCAVA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 96, pl. 16.

(See also vol. 8, pt. 1.)

This species is common in the *S. demissa* bed, where it attains its usual large size and form. It does not commonly occur above this bed, though a single specimen has been found in the Encrinal limestone on the lake-shore. Several specimens were found immediately below it, and others in the shale and calcareous beds between the Trilobite and Pleurodictyum beds.

91. STROPHEODONTA (LEPTOSTROPHIA) PERPLANA, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 98, pl. 11, 12, 17, 19.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 284.

This species has a greater vertical range than either of the preceding, appearing in the shale and limestone down to the Strophalosia bed. It is common and occasionally abundant throughout the Lower shales, and occurs in considerable numbers in the *S. demissa* bed, though it is by no means as common as *S. demissa.* In the Encrinal limestone it is abundant, and it likewise characterizes the lower two or three feet of the Moscow shales. The specimens in this shale are usually large and well formed.

92. STROPHEODONTA (DOUVILLINA) INEQUISTRIATA, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 106, pl. 18.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 284.

This species has a somewhat greater vertical range than the preceding. It appears first in the shales and limestones above the Strophalosia bed, and is not uncommon in the Trilobite beds. The rock between these and the *S. demissa* bed has, however, furnished no specimens. In the *S. demissa* bed it becomes abundant, appearing as gibbous specimens ranging in width up to an inch or more. It is scarcely less abundant than the *S. demissa.* Above this bed it is far less numerous, and in the Encrinal limestone it is outnumbered by *S. perplana.* It appears to be absent from the

lowest part of the Moscow shales, but reappears suddenly between three and five feet above the Encrinal limestone. After that it does not appear again in these shales.

93. STROPHEODONTA (PHOLIDOSTROPHIA) NACREA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 104, pl. 18.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 284.

This little species is most characteristic of the lower Trilobite bed, where it occurs in considerable number and perfection. It is rare below these beds. only a few specimens having been obtained, but is not known in or below the Strophalosia bed. Above the Trilobite beds it is found only in the *Modiomorpha subalata* bed and in the Encrinal limestone, where it suddenly reappears in considerable quantity. It then disappears from this region.

94. STROPHEODONTA (LEPTOSTROPHIA) JUNIA, Hall.

1867, Hall, (*S. textilis*), Pal. N. Y., vol. 4, p. 108, pl. 18.

1892, J. Hall, and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 284, pl. 15.

A few fragmentary specimens of this species were found in the *S. demissa* bed.

95. STROPHEODONTA PLICATA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 114, pl. 63.

(See also vol. 8.)

This species was first described from Iowa City, and subsequently from Independence, Iowa. In the *S. demissa* bed occur several small Stropheodontas with coarse, rather angular plications, and unlike any other form in the Hamilton of New York. I refer them to this species, for though the plications are more angular than those of the type specimen, the difference appears not to be sufficient for specific distinction. A well marked pedicle-valve has about thirteen plications near the beak, while near the front the number is nearly twice that, from intercalation. A stronger plication marks the centre of the valve. The area is narrow, linear, somewhat concave, and vertically striated, the margins strongly crenulated. The cardinal process of the brachial valve is strongly bilobed, the area linear, and the interior surface minutely pustulose.

A small brachial valve measures 11 mm. in width, by 8 mm. in height. In one specimen, apparently of this species, the cardinal angles are produced into mucronate extensions.

Genus Chonetes, Fisher.

96. CHONETES MUCRONATA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 125, pl. 20, 21.

This form is not very common at Eighteen-mile creek, where it is mainly restricted to the lower Moscow shales. Several specimens were obtained from the shales and limestones below the Trilobite beds, the species occurring at intervals down to, and in the Marcellus shales. The variety *laticosta* occurs occasionally, and this latter form is also found in the Encrinal lime stone. The various specimens from the Moscow shales show gradations between this and the next form, suggesting the possibility that the two represent different phases of one and the same species.

97. CHONETES DEFLECTA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 126, pl. 21.

This species occurs abundantly in the lower Moscow shales, between two and three feet above the Encrinal limestone. The specimens are large, very convex, and closely striated by numerous rounded, rather coarse striae. Specimens showing the laterally deflected spines like those of *C. mucronata*, are not uncommon. Examples also occur which show an approximation in their striae to the latter form, suggesting the possible identity of the two, as intimated by Professor Hall. A few specimens from the Encrinal limestone have been referred to this species. It appears to be absent from the shales down to the Trilobite beds, below which it is occasionally found. No specimens have been noticed below the Strophalosia bed.

98. CHONETES SETIGERA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 129, pl. 21.

This species is rare at Eighteen-mile creek. A specimen showing the characteristic spines and form has fewer striae. It was found two or three feet below the Encrinal limestone at Section C. Two specimens from Section B, seventeen to twenty-one feet below the Encrinal limestone, are probably of this species. In the lower beds of the group it is somewhat more abundant, specimens having been obtained in the Pleurodictyum layers, and in the transition shales on the lake shore down to twelve feet below the Strophalosia bed.

99. CHONETES SCITULA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 130, pl. 21.

This species occurs scattered throughout the Lower shales from the Encrinal limestone to the Marcellus shales, occasionally becoming abundant and characteristic. One of the largest and best specimens found measured 11 mm. in width, by 8 mm. in height. In a large collection there occur numerous specimens which show an approximation to the next form, especially in the stronger development of two of the striae near the centre, and the consequent bicarinate aspect of the beak, where these approach each other. The association of this feature with specimens varying in form between the typical *C. scitula* and the typical *C. lepida*, points to the existence of a close relationship between the two forms, and I am inclined to regard them as different phases of the same species. Some specimens have been found in the Encrinal limestone, and a few from the lower two feet of the Moscow shales are referred to this species. It has also been observed in the upper Moscow shales.

100. CHONETES LEPIDA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 132, pl. 21.

This is the most common species of *Chonetes* in the Hamilton shales of Eighteen-mile creek. It is everywhere abundant, in some layers extremely so. It has the same distribution as the preceding species, being everywhere associated with it, but usually much more abundantly represented. Gradations between typical forms, and those approximating to the preceding are common. It has not been observed in the Encrinal limestone, and is rare in the Moscow shales.

This and the preceding species characterize the Hamilton shales, while *C. mucronata* and *C. deflecta* are more abundant in the Moscow shales above.

101. CHONETES CORONATA, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 133, pl. 21.

This is not an uncommon form, being restricted however, with slight exceptions, to the Encrinal limestone and the foot of shale immediately below it. Outside of these layers it has only been found in the Pleurodictyum beds, and in the shale immediately above. In the Encrinal limestone specimens, the concentric striae are well marked, and the interior of the brachial valve is strongly pustulose or almost spinous, with the points arranged along the elevated ribs.

Genus **Productella**, Hall.

102. PRODUCTELLA NAVICELLA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 156, pl. 23.

This species is rare and has been found only in the Encrinal limestone. The specimens are small, with the shell partly exfoliated, but show the spine bases, which are more pronounced on the front of the shell.

103. PRODUCTELLA SPINULICOSTA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 160, pl. 23.

This is the common form of productoid shell in the Hamilton group of this region. It occurs in all stages of preservation, usually, however, more or less crushed. It has been observed in most of the beds of the Lower shale, down to the Strophalosia bed, and is occasionally abundant. It is rare in the Encrinal limestone and has not been observed in the lower Moscow shales. In the upper Moscow shales it occurs two to three feet below the Styliola band, at Section F. Near the lower end of this section the strata are thrown into a slight anticlinal fold of small extent, and it is there that the specimens occur. They are all very badly crushed, but preserve the characteristic spine bases. Numerous slender elongated and curved spines occur, most of which are detached from the shell and lie scattered on the rock surface. The specimens figured by Hall on Pl. 23, fig. 34, Pal. N. Y. vol. 4, probably came from this locality.

Genus **Strophalosia**, King.

104. STROPHALOSIA TRUNCATA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 160, pl. 23.

1892, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. 1, p. 314, pl. 15B, 17.

I have not found this species at Eighteen-mile creek, but on the lake shore at Hamburgh-on-the-lake it occurs in great numbers in a thin band of limestone, the Strophalosia bed, to which it is practically restricted. A single specimen was found in the Nautilus bed just overlying. It likewise occurs in the Marcellus shales.

Genus Spirifer, Sowerby.

105. Spirifer mucronatus, Conrad.

1867, Hall, Pal. N. Y., vol. 4. p. 216, pl. 34.

This is the most abundant species of *Spirifer* in the Lower shales, being well represented in nearly all the layers below the Encrinal limestone. It appears in the lowest beds into which it passes from the transition shales. In the *S. demissa* bed and in the shales immediately above, this species is extremely abundant. Throughout those shales specimens occur, showing the mucronate extensions of the hinge line, one of which from the lower beds of the shale measures 15 mm. in height by 100 mm. from tip to tip of the mucronate points. In some of the higher layers, the narrow bulging form appears, which resembles *S. consobrinus*, D'Orb. In the Encrinal limestone this species is very rare, a few specimens only having been found. These do not show the ordinary characteristics, being in some cases much extended laterally, without mucronations, and with a number (20 or more) of well marked, rounded plications which are crossed by zigzag concentric lines. The hinge area of these specimens is larger than that of ordinary specimens from the shale, resembling more that of *S. consobrinus*. Only two specimens of this species have been found in the lower part of the Moscow shale. Its place here seems to be taken by the *S. consobrinus* which occurs in considerable numbers. Near the top of the Moscow shales a few fragments and casts of this species were found. The prevailing form at this level is *S. Tullius*.

106. Spirifer Tullius, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 218, pl. 35.

This species is represented by a considerable number of specimens, most of which, however, are small. The species has not been found outside of the Moscow shales, and it appears to be restricted to the upper part of that rock, the specimens found coming from between one and one-half and three feet below the Styliola limestone. They scarcely exceed 8 mm. in width by 5 mm. in height, though a few specimens are larger. None, however, approach in size those figured on pl. 35, vol. 4, Pal. N. Y. The plications on each side of the fold and sinus scarcely have the number found in the full-grown specimens. The radiating striations are shown in the majority of the specimens.

107. SPIRIFER SCULPTILIS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 221, pl. 35.

This species was obtained only from the Encrinal limestone, and only a few specimens were found. The specimens are usually exfoliated but the characteristic lamellæ are well shown.

108. SPIRIFER CONSOBRINUS, D'Orbigny.

1850, d'Orbigny, Prodr. d. Paleont. t. 1, p. 98.

1867, Hall, (S. zigzag) Pal. N. Y., vol. 4, p. 222, pl. 35.

This species has been found only in the Moscow shales at Eighteen-mile creek, where it occurs quite abundantly in the beds from two to five feet above the Encrinal limestone. The typical forms are the most abundant, but some specimens occur which might at first glance be mistaken for robust specimens of *S. mucronatus.* The small number of plications, the even zigzag concentric lines, and the relatively high and curving area of the pedicle-valve, however, distinguish this species. The variety designated as *S. Clio* by Hall occurs occasionally. A comparison with *S. mucronatus*, from Thedford Ontario, is made above.

109. SPIRIFER GRANULOSUS, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 223, pl. 36, 37.

1893, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. ii, p. 39.

This species is eminently characteristic of the Demissa and Pleurodictyum beds, in both of which it occurs in great abundance. Two specimens were obtained at Section C, about a foot below the *S. demissa* bed. The specimens from the latter are robust, and usually in a fairly perfect condition, with both valves intact. Those from the Pleurodictyum beds are likewise robust, and usually overgrown by bryozoa. The species occurs sparingly in the shales below the Trilobite layers. It is rare in the Nautilus bed, and extremely so in the Strophalosia bed. It has not been observed below this level. The species is common in the upper part of the Encrinal limestone, where the variety with the angular sinus (*S. Clintoni*, Hall) is likewise abundantly represented. The species does not usually occur above the Encrinal limestone, though a much worn fragment was found in the lower Moscow beds as before noticed.

110. SPIRIFER AUDACULUS, Conrad.

1867, Hall (*S. medialis*), Pal. N. Y., vol. 4, p. 227, pl. 38.

1893, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. ii, p. 39.

This species makes its first appearance in the Pleurodictyum beds, where it is not infrequent. It is rare in, or absent from, the Trilobite beds, but is found in some of the shales between them. It appears to be absent from the shales above the Trilobite beds for a considerable height, appearing again about four feet below the Encrinal limestone. It is abundant in the *S. demissa* bed, and common in the Encrinal limestone. It occurs sparingly in the lower Moscow shales, associated with *S. consobrinus*. The variety *Eatoni* (Hall), occurs here occasionally.

111. SPIRIFER ANGUSTUS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 230, pl. 38*a*.

This species is found in the *S. demissa* bed where it is rare. A small specimen somewhat crushed, has fifteen plications on each side of the fold and sinus. Another, a perfect specimen, has about twenty-five plications on each side of the fold and sinus. The width of this specimen is 27 mm., its height 9 mm. and height of the area 7 mm. A small specimen with the area somewhat more arcuate may belong to this species.

112. SPIRIFER MACRONOTUS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 231, pl. 38*a*.

This species is common in the *S. demissa* bed and in the Encrinal limestone, though not as abundant as *S. audaculus*, with which it is usually associated. At Section C, several specimens were found one and one-half to three feet below the Encrinal limestone and few were obtained from the shale below the Trilobite beds at Avery's creek. Although typical specimens are easily recognized wherever occuring, there are others which show a gradation towards the characters of *S. audaculus*, the two being often indistinguishable. They should probably be united.

113. SPIRIFER ASPER, Hall.

1858, Hall, Geol. Surv. of Iowa, vol. 1, pt. 2, p. 508, pl. 4.

This species is fairly well represented in the *S demissa* bed. The specimens rarely show more than fifteen plications on each side of the median sinus. The granules are coarser in our specimens than they are represented for the

western form, and on well preserved specimens they are to be found on the hinge area. The delthyrium is narrow and the area on each side distinctly grooved as in *S. angustus.* In a number of specimens the beak is slightly incurved, and the area consequently somewhat concave. This may be partly due to compression, but in some cases it is normal. A typical pedicle-valve measures 26 mm. along the hinge line. The height of the cardinal area is 12 mm. and the height of the valve 13 mm.

114. SPIRIFER FIMBRIATUS, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 214, pl. 33.

This species occurs as low as the Pleurodictyum beds, but it is very rare. With a few exceptions from the shales of this level, I have found it only in the *S demissa* and Stictopora beds and in the upper Encrinal limestone. It is very abundant in the former bed but the test is seldom well preserved.

115 SPIRIFER SUBUMBONUS, Hall.

1867, Hall, Pal. N. Y.; vol. 4, p. 234, pl. 32.

This species is rare at Eighteen-mile creek. A single specimen showing the characteristic surface markings was found at Section C, one and one-half to three feet below the Encrinal limestone. In the upper Moscow shales, down to four feet from the top, but principally between one and one-half and two and one-half feet from the top, occur a number of specimens of the species, none, however, showing the pits resulting from partial exfoliation.

Genus **Ambocœlia**, Hall.

116. AMBOCŒLIA UMBONATA, Conrad.

1867. Hall, Pal. N. Y., vol. 4, p. 259, pl. 44.

This is one of the most abundant fossils in the shales of the Hamilton group at Eighteen-mile creek. It occurs in the Lower shales, in the Encrinal limestone, and in the Moscow shales. In the latter it constitutes layers several inches thick where almost no other fossil is found. It is rare in the Encrinal limestone, but common in the Lower shales, and in the transition shales down to twenty-two feet below the Strophalosia bed. It has also been noticed in the Marcellus shales.

116(*a*) AMBOCŒLIA UMBONATA var. NANA. n. var.

Shell small. Pedicle-valve ventricose, broader than the typical forms of the species. Height proportionally less than that of ordinary forms. Sinus

well marked and deep. Brachial valve convex, slightly ventricose below the beak, regularly sloping to the base and lateral margins. Width about one and one-third times the height. Beak of brachial valve elevated above the hinge line, which is less than the greatest width of the shell, and has its extremities rounded. Area of brachial valve linear, that of pedicle-valve high. In the center of the brachial valve there is usually a shallow depression, which becomes wider towards the front. Entire surface covered by numerous elongated pits like those of *A. spinosa*, Clarke, and by concentric striae, which become strong at intervals. On the brachial valve the pits have a distinctly radial arrangement. On a well preserved specimen a part of the surface shows short delicate spinules.

Ambodœlia umbonata, var. *nana*, x 3.

Fig. 3, Cardinal view; fig. 4, profile; fig. 5, ventral view; fig. 6, dorsal view; fig. 7, a portion of the surface (x 10), showing elongate pits and the bases of the spinules which lay in them.

This variety is characterized by its uniformly dwarfed size, its convex brachial valve, and the strongly marked pits on its surface. The proportions are likewise different from those of the ordinary forms of the species.

Measurements of several specimens resulted as follows:

	1	2	3
Pedicle-valve:			
height	6.3mm.	5.9mm.	5. mm.
width	7. mm.	6.6mm.	5.8mm.
depth	3.3mm.	3. mm.	2.5mm.
Brachial valve:	1	2	3
height	5.5mm.	5. mm.	4.5mm
width	7. mm.	6.6mm.	5.8mm.
depth	2. mm.	1.5mm.	1.2mm.

The brachial valve might easily be mistaken for that of a *Spirifer subumbonus*, Hall, but the pedicle-valve has all the characteristic features of *A. umbonata*, varying only in the proportion of height to width. From *A. spinosa*, Clarke, this variety may prove to differ in the form and proportions of the brachial valve.

This variety seems to be confined to the Nautilus bed, where it occurs in great abundance. Three very small specimens of this form have however been found in the Strophalosia bed just beneath. These have the sinus in the pedicle-valve shallow and broad, and they also have a distinct depression near the front of the brachial valve. The pits are shorter and more pronounced. Altogether they approach more nearly *Spirifer subumbonus* though the characters are entirely those of an *Ambocœlia.*

117. AMBOCŒLIA PRÆUMBONA, Hall.

1867, Hall, Pal. N. Y. vol. 4, p. 262, pl. 44.

This species is as abundant in the upper two or three feet of the Moscow shales as *A. umbonata* is in the lower. I have found it as low as four feet below the Styliola band, but it is mainly restricted to the upper portion of the shale. It is abundant in the limestone layer forming the top of the Moscow shales at Section H, where, as in the shale, it is associated with *Schizobolus truncatus* and *Liorhynchus multicostus.* A large brachial valve of this species from the upper shale of Section G, measure 18.5 mm. in width by 13.5 mm. in height. The species has not been observed below this level.

118 AMBOCŒLIA SPINOSA, Clarke.

1894, Clarke, 13th Ann. Rep. State Geol. N. Y. vol. 1, p. 177, pl. 4.

This species was described from a brachial valve found in the Hamilton shales of the Livonia salt shaft. The long hinge line, the upturned margins of the valve, a low median elevation, and the elongated impressions of strong surface spinules were given as characteristic features. I have found what appears to be this shell, in considerable numbers at Section B, between eight and twenty-three feet below the Encrinal limestone. A few specimens occurred at Section F, in the Moscow shales one and one-half to two and one half feet below the Styliola band. In general appearance these specimens do not differ much from *A. umbonata*, and this is especially true of the pedicle-valve. The front of this valve appears somewhat more regularly rounded, and the beak slightly more incurved than in ordinary specimens of *A. umbonata.* A large pedicle-valve measures 8 mm. in width with the height about the

same. A brachial valve measures 7.3 mm. on the hinge, and 5 mm. in greatest height. Another brachial valve measures 8 mm. on the hinge by 6 mm. in height. The mould of the interior of a brachial valve indicates raised muscular areas, with a fine median septum dividing them, and blunt ridges on either side, which pass forward with a gradual outward sweep. The internal mould of a pedicle-valve shows a narrow muscular ridge with a depression along the centre. The sides for some distance are strongly pustulose.

Frequently the impression of a valve is all that is found and this shows raised markings corresponding to the impressions in the valve. Rarely specimens are found preserving any indication of spines. Without a lens it is usually not possible to see the impressions on the surface of the shell, and in such cases it is not easy to distinguish these specimens from *A. umbonata.*

Genus **Cyrtina**, Dalman.

119. CYRTINA HAMILTONENSIS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 268, pl. 27, 44.

This species is not uncommon in the upper part of the Hamilton shales. The specimens are usually more or less crushed and distorted, but perfect specimens occasionally occur. They are mostly small but otherwise characteristic. A single crushed valve from four to five feet below the Encrinal limestone is referred to this species. Another specimen was found about 10 feet below the Encrinal limestone, and a few in the shale below the Trilobite beds and in the Pleurodictyum beds. It is very rare in the Moscow shales, a single specimen having been found.

119 (a). CYRTINA HAMILTONENSIS, var. RECTA, Hall.

1885, Hall, Pal. N. Y., vol. 4, p. 270, pl. 44.

This variety is rare in this vicinity. A few specimens were found in the upper Pleurodictyum bed.

Genus **Nucleospira**, Hall.

120. NUCLEOSPIRA CONCINNA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 279, pl. 45.

This species is very common in the upper foot of the Hamilton shale. Many specimens preserve the setæ, while others show simply the pustulose markings, and still others are perfectly smooth. The species occurs as ow as the Nautilus bed, but is not very common. It is found associated with

Athyris spiriferoides nine feet below the Encrinal limestone, but is rare. A single specimen from the limestone is referred to this species with some doubt. The species is again sparingly represented in the lower Moscow shales, three to five feet above the Encrinal limestone.

Genus **Athyris**, McCoy.

121. ATHYRIS SPIRIFEROIDES, Eaton.

1867, Hall, Pal. N. Y., vol. 4, p. 285, pl. 46.

This is one of the characteristic fossils of the Hamilton group of this region. It is abundant, however, only at a few levels. The layer most prolific in specimens is about nine feet below the Encrinal limestone (*Athyris spiriferoides* layer). The specimens in this layer are usually well preserved owing to the presence in considerable number of calcareous concretions, some of which are filled with this brachiopod. In the shale between the lower and middle Trilobite layers the species is likewise abundant. It occurs sparingly in the shale between these two levels, with the exception of a calcareous bed twenty feet below the Encrinal limestone where it is well represented. Below the Trilobite beds it is not uncommon down to the Nautilus bed, below which it has not been observed. Above the Athyris bed, it is well represented in the remaining portion of the Hamilton shales. It is not an uncommon form in the Encrinal limestone, and it is fairly well represented in the lower five feet of the Moscow shale. Several impressions were found in the upper Moscow shales, about two feet below the Styliola band.

Genus **Meristella**, Hall.

122. MERISTELLA HASKINSI, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 306, pl. 49.

A few specimens mainly small, and all exfoliated, are referred to this species. They are from the Encrinal limestone.

123. MERISTELLA ROSTRATA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 307, pl. 50.

Among the collections from the Encrinal limestone are two small specimens of this species, both of the ordinary size, but differing in shape. One shows radiating striae, and corresponds to fig. 17, pl. 50, while the other is more like figs. 15 to 18, pl. 63 (Pal. N. Y. vol. 4), though smaller.

Genus **Atrypa**, Dalman.

124. ATRYPA RETICULARIS, Linné.

1867, Hall, Pal. N. Y., vol. 4, p. 316, pl. 51, to 53*a*.

I have not found this species below the *Athyris* layer, though above it, in certain layers, it is by no means rare. It is common in the *S. demissa* bed where the specimens are well preserved. It has not been noticed in the Encrinal limestone, but it occurs again in the lower Moscow shales, and is common in the coral layer, though less so than the following.

125. ATRYPA ASPERA, Dalman.

1867, Hall, Pal. N. Y., vol. 4, p. 322, pl. 53*a*.

This species has a much more restricted distribution than the preceding. I have found it only in the lower Moscow shales, where it is the most abundant brachiopod of the coral layer. A single specimen was found at a little distance above this.

The characteristic spines found in most of the specimens from Moscow, N. Y., are seldom preserved in the Eighteen mile creek specimens, only three crushed specimens from the coral layer preserving any trace of them. The specimens are usually robust and well formed, and otherwise correspond to the specimens from the Genesee valley. No signs of wearing are exhibited by the shells, and the loss of spines is possibly to be attributed to maceration in shallow water where little sediment was accumulating, or to slight wave or current action.

Genus **Vitulina**, Hall.

126. VITULINA PUSTULOSA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 410, pl. 62.

This species is quite common in the Encrinal limestone, more than twenty specimens having been obtained. These occur, however, usually as separate valves, both pedicle and brachial, and all are exfoliated, consequently do not show the surface pustules. The specimens are all small, the largest one obtained measuring 12 mm. in height, by 14 mm. in width. I have not observed the species outside of this limestone.

Genus **Camarotœchia**, Hall.

127. CAMAROTŒCHIA HORSFORDI, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 339, pl. 54 (Rhynchonella).

1893, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. ii, p. 189, pl. 57.

This species is rare at Eighteen-mile creek. I have found it in the Encrinal limestone, and in the shale immediately below. A doubtful specimen from the Nautilus bed may belong here. A specimen from the lower Moscow shales three feet above the bottom also belongs to this species.

128. CAMAROTŒCHIA SAPPHO, Hall.

1867, Hall, Pal. N. Y. vol. 4, p. 340, pl. 54.

1893, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. ii, p. 189, pl. 57.

This is the most common species of the genus in these shales. It is sparingly represented in the Pleurodictyum beds, but has not been noticed below them. The species occurs quite abundantly from seventeen to twenty-one feet below the Encrinal limestone. Above this it does not occur again until within three feet of the Encrinal limestone, between which and the limestone, as well as in the latter rock, a number of specimens were found. On one of these the plications are too few in number to agree with the typical forms with which it otherwise corresponds.

129. CAMAROTŒCHIA DOTIS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 344, pl. 54.

1892, Hall and Clarke, Pal. N. Y., vol. 8, pt. ii, p. 189, pl. 57.

This species, originally described from a calcareous layer in the Hamilton of Eighteen-mile creek, occurs, so far as I am aware, at that place only in the Encrinal limestone, where it is rare. In the Nautilus bed of Avery's creek and the lake shore, however, it is very common, the specimens being of average size. The number of plications on the fold varies from four to five, and in the sinus from three to four. Occasionally additional plications appear on the sides of the fold. The plications are usually rounded, sometimes strongly so. Four measurements gave dimensions as follows: Length 10, 9.5, 10, 9, mm and width 12, 12, 12, 10, mm respectively. A doubtful specimen was obtained from the Strophalosia bed.

130. CAMAROTŒCHIA, sp.

A single pedicle-valve with few, distant and rounded narrow plications, found in the Encrinal limestone, has the plications deeply bifid at the front and there are apparently but two in the sinus, and four on either side of it. The general form is like that of *C. Sappho*, but the interspaces are too wide and the sinus too shallow, to allow its being referred to that species.

Genus **Liorhynchus**, Hall.

131. LIORHYNCHUS MULTICOSTUS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 358, pl. 56.

This is the most abundant rhynchonelloid shell in the Hamilton group of this region. It occurs throughout the group, but is usually restricted to special layers, where it is often found in such abundance that one specimen obliterates the characters of the other. It occurs sparingly in some of the lowest beds, but becomes more abundant farther up, especially where concretionary masses occur in the shale. It continues abundant up to about fourteen feet below the Encrinal limestone, after which it becomes very rare and practically disappears for a time, reappearing again in the lower Moscow shales where it is at first rare. It becomes somewhat more abundant as we ascend, until within about a foot or two of the top it has become extremely abundant again. At this level also occur large specimens which have the lateral plications rather indistinct, and only three plications in the sinus. also a number of small, flat, scarcely plicated shells which must be referred to this species. The whole tendency in the specimens from these shales is towards an approximation to the features of *L. quadricostatus* of the Genesee slate, and occasionally a specimen is found which is practically indistinguishable from that form. The specimens from the concretions usually show the normal characters of the species, as do also many of the specimens from the shale. The plications in these are well developed on the lateral slopes, becoming, however, obsolete towards the beak. In rare cases do they reach the beak. Bifurcation is common in the plications of the fold and sinus, and is not infrequent in those of the lateral slopes, especially near the top. The specimens from the limestone concretions are usually somewhat smaller than those from the shale.

132. LIORHYNCHUS LIMITARIS, Vanuxem.

1867, Hall, Pal. N. Y., vol. 4, p. 356, pl. 56.

This species occurs in the lower eight or ten feet of the transition shales, and in the upper Marcellus.

133. LIORHYNCHUS DUBIUS, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 364, pl. 56.

At Section 13, at a depth of about twenty feet below the Encrinal limestone, two small valves were found which correspond essentially with fig. 22 of the above plate. No fold or sinus is indicated in the specimens, and I refer them provisionally to this species, which was originally described from the Marcellus shale.

Genus **Centronella**, Billings.

134. CENTRONELLA IMPRESSA, Hall.

1867, Hall, Pal. N. Y. vol. 4, p. 402, pl. 61*a*.

This shell is known to me only from the Encrinal limestone of Eighteen-mile creek, where it occurs in considerable numbers. The specimens are small and the brachial valve usually bears the characteristic central impression for the entire length. About thirty-five specimens were obtained.

Genus **Cryptonella**, Hall.

135. CRYPTONELLA PLANIROSTRA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 395, pl. 61.

This is another species which is practically restricted to the Encrinal limestone though several specimens from the shale below have been referred to it. The limestone specimens are usually robust and well developed, though most of them are undersized. The specimens from the upper part of the Hamilton shales are usually in a crushed and imperfect condition, and do not exhibit the characters well. Doubtful specimens were obtained from the Pleurodictyum beds, but these may prove to belong to the next.

136. CRYPTONELLA RECTIROSTRA, Hall.

1867, Hall, Pal. N. Y., vol. 4, p. 394, pl. 61.

This species is common in the upper Pleurodictyum bed and in the bed just overlying, but has not been observed either above or below these.

Genus **Cranæna**, Hall and Clarke.

137. CRANÆNA ROMINGERI, Hall.

1867, Hall, (Terebratula) Pal. N. Y., vol. 4, p. 319, pl. 60.

1893, J. Hall and J. M. Clarke, Pal. N. Y., vol. 8, pt. ii, p. 297, fig. 215.

This species occurs in the same beds as the preceding, though it is less common. A small specimen from the lowest Trilobite bed appears to belong to this species.

Genus **Tropidoleptus**, Hall.

138. TROPIDOLEPTUS CARINATUS, Conrad.

1867, Hall, Pal. N. Y., vol. 4, p. 407, pl. 62.

This fossil is almost entirely restricted to the Encrinal limestone at Eighteen-mile creek. A normal specimen was obtained about twenty feet below the Encrinal limestone. At Avery's creek and on the lake shore this species occurs sparingly between the Trilobite and Strophalosia beds. In the Encrinal limestone it is abundant, and the specimens are often large. It has not been found in the Moscow shales. At Morse creek it is common a few feet below the Encrinal limestone.

CRINOIDEA.

Genus **Taxocrinus**, Phillips.

139. TAXOCRINUS, sp.

1862, Hall, 15th Rep. N. Y. State Mus. Nat. Hist. p. 118, pl. 1.

A specimen of an undetermined species was found in the Moscow shale about four feet above the Encrinal limestone.

Genus **Ancyrocrinus**, Hall.

140 ANCYROCRINUS BULBOSUS, Hall.

1862, Hall, 15th Rep. N. Y. State Cab. Nat. Hist. p. 90, pl. i.

This species occurs in the lower Moscow shale, three to five feet above the Encrinal limestone, and in the *S. demissa* bed, *Hadrocrinus pentadactylus*, Grabau (Ms) from the lower Moscow shales.

Crinoid joints, stems, and plates. These bodies are common in the *S. demissa* and overlying shales and in the Encrinal limestone, but are rare in or absent from other parts of the group. A few unidentified calices are from the lower Moscow shales. A number of distinct species are indicated.*

*The following species have since been determined *Gennæocrinus Nyssa*, Hall, and *G. eucharis*, Hall, from the *S. demissa* bed.

BRYOZOA.

Genus **Stictopora**, Hall.

141. STICTOPORA INCISURATA, Hall.

1887, Hall, Pal. N. Y., vol. 6, p. 241, pl. 60.

This species is common and even abundant in some calcareous layers of shale just above the *S. demissa* bed, at Section D. Here the specimens are usually weathered out, and may be picked up in great numbers. It occurs in the *S. demiesa* bed and to some extent in the underlying strata. The lowest beds in which I have found it are the Pleurodictyum beds, where, however, it is not very common. It is rare in the Encrinal limestone, and has not been noticed in the shales above.

142. STICTOPORA SINUOSA, Hall.

1887, Hall, Pal. N. Y., vol. 6, p. 247, pl. 61.

A single specimen of this species was obtained from the shale two feet below the lower Trilobite bed at Avery's creek.

Genus **Tæniopora**, Nicholson.

1887, Hall, Pal. N. Y., vol. 6, page 263, pl. 64.

143. TÆNIOPORA EXIGUA, Nicholson.

This species is rare, several fragments only having been found in the Demissa bed, and the shales above (Stictopora bed) associated with the preceding.

Genus **Botryllopora**, Nicholson.

1887, Hall, Pal. N. Y., vol. 6, p. 282, pl. 64.

144. BOTRYLLOPORA SOCIALIS, Nicholson.

This species occurs occasionally in the shale and semi-calcareous layers below the Trilobite beds in the ravine of Avery's creek, and on the lake shore.

Genus **Reptaria**, Rolle.

1887, Hall, Pal. N. Y., vol. 6, p. 274, pl. 65.

145. REPTARIA STOLONIFERA, Rolle.

A single zoarium only of this fossil was found encrusting an *Orthoceras* (*O. constrictum?*) at Section D in the *S. demissa* bed.

146. LOCULIPORA PERFORATA, Hall.

1884, Hall, 36th Rep. N. Y. State Mus. Nat. Hist. p. 65.

1888, Hall, 41st Rep. N. Y. State Mus. Nat. Hist. pl. 10.

This species is represented in the *S. demissa* bed by several fragments of large fronds.

Genus **Fenestella**, Lonsdale.

147. FENESTELLA EMACIATA, Hall.

1884, Hall, 36th Rep. N. Y. State Mus. Nat. Hist. p. 68.

1888, Hall, 41st Rep. N. Y. State Mus. Nat. Hist. pl. 65.

This species is represented by fronds and fragments in the *S. demissa* bed It is the most abundant fenestelloid in these shales.

148. FENESTELLA.

Several other species of *Fenestella* occur in these shales, as well as species of other genera, but the present state of the literature on these fossils does not admit of their determination, and they are reserved for future study.*

ANTHOZOA

Genus **Favosites**, Lamarck.

149. FAVOSITES ARGUS, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 13.

A large specimen of this species from Eighteen-mile creek probably came from the Demissa bed.

150. FAVOSITES HAMILTONIÆ, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 34.

This species is common in the Encrinal limestone where it often occurs in large heads. I have not observed the species outside of this rock.

Genus **Pleurodictyum**, Goldfuss.

151. PLEURODICTYUM STYLOPORA, Eaton.

1876, Hall, Pal. N. Y., III, Dev. Foss., pl. 3.

This species is entirely restricted to the three calcareous layers between five and seven feet below the Trilobite beds, (Pleurodictyum layers) where

* The following have since been determined; from the *S. demissa* bed: *Fenestella planiramosa*, Hall; *Reteporina triata*, Hall; *Unitrypa scalaris*, Hall; *Fistulicella plana*, Hall; *Paleschara intercella*, Hall; *P. reticulata*, Hall, *P. amplectens*, Hall; *Lichenalia stellata*, Hall; *Ptylodictya pluma*, Hall. Some of these, with many other undetermined ones, *Streblotrypa Hamiltonensis*, Nicholson, occur in the Bryozoa beds, two feet below the Trilobite beds. *Rhombopora polygona*, Hall, was found four feet below the Encrinal limestone.

it is extremely abundant, especially in the middle one. The specimens are of fair size, and usually well developed. Occasionally one is found upside down in the rock.

Genus **Streptelasma**, Hall.

152. STREPTELASMA RECTUM, Hall.

1876, Hall, Pal. N. Y. Ills. Dev. Foss., pl. 19.

This is the most common coral at Eighteen-mile creek. It is abundant in the shale below and between the Trilobite beds, and occasionally occurs in the Nautilus bed. It is common in the *S. demissa* bed, and extremely so in the lower Moscow shales.

153. STREPTELASMA UNGULA, Hall.

1876, Hall, Pal. N. Y., III, Dev. Foss., pl. 19.

This species is not very common. It occurs in the lower Moscow shale with the preceding, between three and five feet above the Encrinal limestone.

Genus **Zaphrentis**, Rafinesque.

154. ZAPHRENTIS SIMPLEX, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 21.

This species is comparatively rare. A few individuals were found in the "coral layer" of the Moscow shales twenty inches above the Encrinal limestone. It is rare in the Encrinal limestone.

Genus **Heliophyllum**, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 23.

155. HELIOPHYLLUM HALLI, Edwards and Haime.

This coral has a very restricted vertical distribution at Eighteen-mile creek, being practically confined to the coral layer of the lower Moscow shales, where it is common. A single specimen was obtained from the *S. demissa* bed. At Morse creek it occurs in the Encrinal limestone.

156. HELIOPHYLLUM CONFLUENS, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 26.

This coral occurs only in the Encrinal limestone. Several specimens were noted in blocks of this rock on the lake shore. On Morse creek it is not uncommon in the lower Encrinal, associated with the preceding.

Genus **Cystiphyllum**, Lonsdale.

157. CYSTIPHYLLUM AMERICANUM, E. and H.

1851, Edwards and Haime, Polyp. Foss. Terr. Pal. p. 464, pl. 13.

This species is well represented in the coral layer of the lower Moscow shales encrusted with bryozoa and other organisms.

158. CYSTIPHYLLUM CONIFOLLIS, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss, pl. 30.

This is the most abundant species of *Cystiphyllum* in the Hamilton group of this region. It occurs in the coral layer and other beds of the lower Moscow shales, and also in the *S. demissa* bed of the Lower shales.

Several other species of *Cystiphyllum* occur in the coral layer but they are not in a satisfactory condition for identification.

Genus **Amplexus**, Sowerby.

159. AMPLEXUS HAMILTONIÆ, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss, pl. 19.

This species is not infrequent in the lower Moscow shales, three to five feet above the Encrinal limestone.

160. AMPLEXUS (?) INTERMITENS, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 32.

This species occurs sparingly in the beds three to five feet above the Encrinal. It is a characteristic Moscow species, occurring in the lower part of this shale at Morse creek, and other localities, but is probably not an *Amplexus.*

Genus **Monotrypa**, Nicholson.

161. MONOTRYPA FRUTICOSA, Hall.

1876, Hall, Pal. N. Y., Ills. Dev. Foss., pl. 38.

This species occurs in the Moscow shales, three to five feet above the Encrinal limestone, in the *S. demissa* bed and in the Pleurodictyum beds. It is not a common species.

Genus **Aulopora**, Goldfuss.

162. AULOPORA SERPENS, Goldfuss.

1876, Rominger, Foss. Corals, p. 87.

This species occurs occasionally encrusting brachiopod shells. I have found it in the *S. demissa* bed and in the *Athyris spiriferoides* bed.

Genus **Craspedophyllum**, Dybowsky

163. CRASPEDOPHYLLUM SUBCÆSPITOSUM, Nicholson.

1874, Nicholson, Geol. Mag. Lond. Dec. 2, vol. 1, p. 58, pl. 4.

This species occurs in the Encrinal limestone, where it forms subcæspitose aggregations. I have observed only a few specimens.

NOTE: The following additional species have been determined since the above was written; *Aulopora tubæformis* Goldfs., *Monotrypa furcata*, Hall, *Trachypora limbata*, Eaton, *Spirorbis angulatus*, Hall and *Cornulite Hamiltoniæ*, *sp.n.*

III. THE LOCAL FAUNAS AND SUBFAUNAS AND THEIR SUCCESSION IN THE HAMILTON GROUP OF THE EIGHTEEN-MILE CREEK REGION.

A. The upper Marcellus.

a. The fauna of the Transition shales.

The thirty feet of shale overlying the Pteropod bed of the Marcellus, while presenting true Marcellus characters in their fauna, nevertheless approximate to the overlying Hamilton sufficiently to warrant their being regarded as in a measure transitional from the typical Marcellus to the typical Lower Hamilton shales, and for that reason they are discussed here.

The following is a complete list of the fossils obtained from these shales:

Crustacea:

*1 Phacops rana. r
2 Cryphæus Boothi. r
6 Primitiopsis punctulifera. r

Cephalopoda:

Orthoceras sp. r

Pteropoda:

14 Tentaculites gracilistriatus. c
15 Styliolina fissurella c

Gasteropoda:

25 Euomphalus (Phanerotinus) laxus. R
33 Bellerophon Leda. R

Lamellibranchiata:

53 Nuculites triqueter r
64 Lunulicardium fragile. c

Brachiopoda:

87 Orthothetes arctostriata. r
96 Chonetes mucronata. r

*The numbers preceding the name correspond to those given in Part II. R=very rare, r=rare, rc=fairly common, c=common, C=very common.

98 C. setigera. r
99 C. scitula. r
100 C. lepida. rc
103 Productella spinulicosta. r
104 Strophalosia truncata. r
105 Spirifer mucronatus. rc
116 Ambocœlia unbonata. rc
132 Liorhynchus limitaris. rc
138 Tropidoleptus carinatus. r
Crinoid stems. r

Of these *Euomphalus* (*Phanerotinus*) *laxus* has not previously been recorded from the Marcellus shales, but this species is found in the Pteropod layers which are undoubtedly of this age. *Primitiopsis punctulifera* has not been noticed from the Marcellus, but a *Leperditia* is recorded.*

In the lower portions of these shales the characteristic Marcellus species predominate: *Styliolina fissurella*, *Lunulicardium fragile*, *Liorhynchus limitaris*, etc. In the upper portion, species forming normal constituents of the lower Hamilton faunas are more abundant, viz.: *Spirifer mucronatus*, *Chonetes lepida*, etc, though the characteristic Marcellus species are by no means absent.

b. The fauna of the Strophalosia bed.

Fossils are numerous in this bed, the most abundant and persistent form being *Strophalosia truncata*, Hall. The gasteropods are quite common, especially *Loxonema* and *Bellerophon Leda*.

Orthoceras exile (?) is another common though poorly preserved form.

The following is the list of species obtained from this bed.

Crustacea:

1 Phacops rana. r
2 Cryphæus Boothi. R

Cephalopoda:

9 Orthoceras subulatum. rc
12 O. exile (?). c

Pteropoda: None.

* See list of Marcellus fossils by J. M. Clarke in report of N. Y. State Geologist for 1888.

Gasteropoda:

30 Pleurotomaria capillaria. rc
31 Loxonema Hamiltoniæ. c
32 L. delphicola (?). rc
33 Bellerophon Leda. C

Lamellibranchiata:

50 Cypricardella bellistriata. R
51 Nuculites oblongatus. rc
52 Nuculites Nyssa. rc
55 Palæoneilo tenuistriata. R
57 P. muta. R
67 Modiella pygmæa. r
68 Tellinopsis subemarginata. R
69 Glyptocardia speciosa. R

Brachiopoda:

104 Strophalosia truncata. C
105 Spirifer mucronatus c
109 S. granulosus. R
116 (a) Ambocœlia umbonata var. nana. r
129 Camarotoechia Dotis (?). R

While this fauna has somewhat departed from the typical Marcellus expression, its most important species are, nevertheless, Marcellus forms, or at least such as occur in the Marcellus. The presence in this rock of a few small specimens of *Ambocœlia umbonata* var. *nana*, is interesting, especially as the specimens show a greater resemblance to *Spirifer subumbona* than do the specimens in the Nautilus bed.

With the disappearance of *Strophalosia truncata*, the Marcellus came to a close in this region, and the true Hamilton epoch began, followed shortly by the appearance of *Nautilus magister* and its associated forms.

B. The fauna of the Lower Hamilton shales, or the *Spirifer mucronatus* fauna.

Throughout the Lower shales *Spirifer mucronatus* appears as the characteristic fossil. It has usually its normal extended form, occasionally however becoming extremely mucronate. It is a very abundant fossil, though in some thin beds in the upper part of the shales and in some of the lowest beds it is

rare. Associated with it in almost every case are *Chonetes lepida* and *C. scitula*. *Phacops rana* also occurs plentifully dispersed throughout nearly all the beds. This fauna I shall call the *Spirifer mucronatus fauna*. Its range is coextensive with the Lower shales, being limited below by the Strophalosia bed, and above by the Encrinal limestone.

The following are its subdivisions in the region under discussion:

a. The Lower Pleurodictyum or Nautilus bed.

This is a bed of calcareous concretionary masses, embedded in shale, the whole resting upon the Strophalosia bed. *Nautilus magister* Hall, is the most important fossil in this bed, this being the source of the type specimens. So far as I have been able to ascertain, this species is not found outside of this bed, and it therefore belongs to the lowest bed of the Hamilton stage in this section. The most abundant fossil and the one characterizing this bed in all its outcrops, is *Ambocœlia umbonata* var. *nana*, and with the exception of the three specimens recorded from the Strophalosia bed (which, as stated above, differ from the type forms), this variety does not occur elsewhere in the Hamilton beds of this region. Associated with it and equally abundant, is *Camarotœchia Dotis* and it, too, is practically restricted to this bed, the few specimens recorded from other beds differing from these in their general appearance. These two species occupy the rock in places to the exclusion of nearly every other form. In this bed *Pleurodictyum stylopora* also makes it first appearance, the specimens, however, not being very numerous. The complete list of fossils obtained from this horizon is as follows:

Crustacea:

3 Homalonotus Dekayi. r

Cephalopoda:

8 Nautilus magister. c

Pteropoda:

17 Coleolus tenuicinctus. r

Gasteropoda:

24 Platyostoma (Diaphorostoma) lineata. r
29 Pleurotomaria Itys (and variety). rc
33 Bellerophon Leda. r

Brachiopoda:

76 Orbiculoidea Lodensis (?). R
91 Stropheodonta perplana. R
99 Chonetes scitula. rc
100 Chonetes lepida. rc
104 Strophalosia truncata. R
105 Spirifer mucronatus. rc
109 S. granulosus. r
116 Ambocœlia umbonata. r
116 (a) A. umbonata var. nana. C
120 Nucleospira concinna. r
121 Athyris spiriferoides. R
127 Camarotœchia Horsfordi. R
129 Camarotœchia Dotis. C

Anthozoa:

151 Pleurodictyum stylopora. rc
152 Streptelasma rectum. r

Comparing the fauna of this bed with that of the Strophalosia bed, it will be seen that the Hamilton epoch was introduced with a radical change in the fauna, the two beds being as distinct in that respect as possible. The Nautilus bed also differs greatly from all succeeding beds.

b. The middle Pleurodictyum bed.

This is the bed in which *P stylopora* has attained its most abundant and most perfect development. The bed is furthermore characterized by the abundant occurrence of large and robust forms of *Spirifer granulosus,* many of which are overgrown with bryozoa and corals.

The fossils of this bed are as follows:

Crustacea

1 Phacops rana. r
3 Homalonotus Dekayi R

Cephalopoda:

Orthoceras sp. r

Gasteropoda:

20 Platyceras Thetis. r
22 P. symmetricum. R

24 Platyostoma (Diaphorostoma) lineata. rc
28 Pleurotomaria lucina var. perfasciata. R
33 Bellerophon Leda. R

Lamelli branchiata:

41 Actinopteria decussata. r
42 A. Boydi. r
46 Modiomorpha concentrica. r
48 M. alta. R

Brachiopoda:

87 Orthothetes arctostriata. rc
88 O. perversa. r
91 Stropheodonta perplana. rc
96 Chonetes mucronata. r
98 C. setigera. R
99 C. scitula. rc
100 C. lepida. rc
105 Spirifer mucronatus. r
109 S. granulosus. C
121 Athyris spiriferoides. rc
128 Camarotœchia Sappho. r
137 Dielasma Romingeri. rc
138 Tropidoleptus carinatus. rc

Bryozoa: Several undetermined.

Annelida:

Cornulites. r
Spirorbis. r

Anthozoa:

151 Pleurodictyum stylopora C
161 Monotrypa fruticosa. r

c. The Upper Pleurodictyum bed.

In this bed *Spirifer granulosus* and *Pleurodictyum stylopora* still continue as the characteristic forms. The complete list of fossils is as follows:

Crustacea:

1 Phacops rana. rc
6 Primitiopsis punctulifera. rc

Cephalopoda:

7 *Goniatites uniangularis. R

Gasteropoda:

Platyceras sp. R

24 Platyostoma (Diaphorostoma) lineata. rc

29 *Pleurotomaria Itys. r

*Bellerophon sp. r

Lamellibranchiata:

36 Pterinopecten conspectus. rc

41 Actinopteria decussata. c

46 *Modiomorpha concentrica. r

47 M. subalata. r

50 Cypricardella bellistriatus. rc

Brachiopoda:

*Orbiculoidea sp. R

87 Orthothetes arctostriata. rc

91 Stropheodonta perplana. rc

97 Chonetes deflecta. r

98 *C. setigera. r

99 C. scitula. rc

101 C. coronata. r

103 Productella spinulicosta. r

105 Spirifer mucronatus. rc

109 S. granulosus. c

110 S. audaculus. rc

114 S. fimbriatus. R

119 Cyrtina Hamiltonensis. r

119 (a) Cyrtina Hamiltonensis var. recta. r

121 Athyris spiriferoides. rc

128 Camarotœchia Sappho. rc

135 Cryptonella planirostra (?) R

136 C. rectirostra. c

137 Dielasma (Cranæna) Romingeri. R

138 Tropidoleptus carinatus. r

Bryozoa:

141 Stictopora incisurata. rc

*Fistulipora sp. r

Annelida:

Spirorbis sp. r

Anthozoa:

151 Pleurodictyum stylopora c

The specimens starred are from a calcareous bed six to seven feet below the lower Trilobite bed, at Wanakah Cliff, which is probably in this horizon.

d. Calcareous bed, four to six inches.

This bed rests on the upper Pleurodictyum bed, a thin layer of shale separating them in most places. Fossils are numerous, *Spirifer granulosus* predominating. This species becomes rare and disappears shortly after, and does not occur again until within a few feet of the Encrinal limestone. *Pleurodictyum stylopora* has completely disappeared from this region. *Rhipidomella* comes in, but otherwise the fauna has not changed very much.

The complete list of fossils observed is as follows:

Crustacea:

1 Phacops rana. rc
2 Cryphæus Boothi. rc
5 *Proetus sp. R

Gasteropoda:

24 *Platyostoma (Diaphorostoma) lineata. rc

Lamellibranchiata:

37 Pterinopecten Hermes. r
41 *Actinopteria decussata. r
42 *A. Boydi. r
46 Modiomorpha concentrica. r
50 Cypricardella bellistriata. r
57 Palæoneilo muta. R
66 Cypricardinia indenta. r

Brachiopoda:

82 *Rhipidomella Vanuxemi. rc
87 Orthothetes arctostriata. r
90 Stropheodonta concava. r
91 S. perplana. rc
92 S. inequistriata. rc

93 *S. nacrea. r
100 Chonetes lepida. rc
101 C. coronata. r
105 Spirifer mucronatus. rc
109 S. granulosus. c
110 S. audaculus. rc
114 *S. fimbriatus. R
119 *Cyrtina Hamiltonensis. r
120 Nucleospira concinna. r
121 Athyris spiriferoides. rc
128 *Camarotœchia Sappho. r
136 Cryptonella rectirostra. c
137 *Dielasma Romingeri. rc
138 Tropidoleptus carinatus. rc

Bryozoa: Several Fenestelloids.

Anthozoa:

152 *Streptelasma rectum. rc

Starred species from Wanakah Cliff.

This layer is succeeded by:

e. Shale two feet. Fossils are not common; the following occur:

Crustacea:

3 Homalonotus Dekayi. R

Cephalopoda:

10 Orthoceras nuntium. R

Gasteropoda:

33 Bellerophon Leda. R

Lamellibranchiata:

50 Cypricardella bellistriata. r
54 Palæoneilo constricta. R

Brachiopoda:

91 Sropheodonta perplana. r
99 Chonetes scitula. r
100 C. lepida. r
105 Spirifer mucronatus. r
109 S. granulosus. R

Bryozoa:

144 Botryllopora socialis. r

Other Bryozoa rare.

Anthozoa:

Monotrypa. r

This is succeeded by:

f. A thin band of a more or less calcareous character, containing Bryozoa in great numbers, and in addition the following species:

Crustacea:

1 Phacops rana. r

6 Primitiopsis punctulifera. r

Gasteropoda:

24 Platyostoma (Diaphorostoma) lineata. R

Brachiopoda:

92 Stropheodonta inequistriata. rc

103 Productella spinulicosta. R

105 Spirifer mucronatus. rc

121 Athyris spiriferoides. c

135 Cryptonella planirostra R.

Bryozoa; Among many others:

141 Stictopora incisurata. c

142 S. sinuosa. R

148 Fenestella sp. c

Above this bed are:

g. Two feet of fissile shale, highly fossiliferous.

They contain the following association of fossils:

Crustacea:

1 Phacops rana. rc

6 Primitiopsis punctulifera. c

Gasteropoda.

24 Platyostoma (Diaphorostoma) lineata. rc

Lamellibranchiata:

34 Aviculopecten princeps. r
46 Modiomorpha concentrica. r
47 M. subalata. R
55 Palæoneilo tenuistriata. R
66 Cypricardinia indenta. rc

Brachiopoda:

78 Craniella Hamiltoniæ. r
82 Rhipidomella Vanuxemi. rc
83 R. leucosia. rc
84 R. Penelope. r
86 R. cyclas. R
90 Stropheodonta concava. R
92 S. inequistriata. rc
93 S. nacrea. R
97 Chonetes deflecta. r
99 C. scitula. c
100 C. lepida. R
103 Productella spinulicosta. rc
105 Spirifer mucronatus. c
109 S. granulosus. R
110 S. audaculus. rc
112 S. macronotus. r
114 S. fimbriatus. rc
116 Ambocœlia umbonata. rc
119 Cyrtina Hamiltonensis. r
120 Nucleospira concinna rc
121 Athyris spiriferoides. c
138 Tropidoleptus carinatus. rc

Anthozoa:

152 Streptelasma rectum. c
Monotrypa (?). r

THE TRILOBITE BEDS.

h. The lowest Trilobite bed.

Phacops rana is the most abundant fossil in this bed, and next to it comes *Cryphæus Boothi.*

The following is a complete list of the fossils found:

Crustacea:

1 Phacops rana. C
2 Cryphæus Boothi. c
2a C. Boothi var callitetes.(?)

Pteropoda:

15 Styliolina fissurella. rc

Gasteropoda:

23 Platyceras attenuatum. r
24 Platyostoma lineatum. r

Lamellibranchiata:

47 Modiomorpha subalata. rc

Brachiopoda:

92 Stropheodonta inequistriata. c
93 S. nacrea. c
99 Chonetes scitula. r
105 Spirifer mucronatus. rc
116 Ambocœlia umbonata. r
137 Dielasma Romingeri. r

Anthozoa:

152 Streptelasma rectum. rc

This bed is succeeded by:

i. Two to three inches of fissile shale in which *Athyris spiriferoides* is especially abundant. The following fossils occur in it;

Crustacea:

1 Phacops rana. r
2 Cryphæus Boothi. r
6 Primitiopsis punctulifera. r

Brachiopoda:

79 Pholidops Hamiltoniæ. r
99 Chonetes scitula. R
100 C. lepida. r
103 Productella spinulicosta. r

105 Spirifer mucronatus. r
110 S. audaculus. r
116 Ambocœlia umbonata. r
121 Athyris spiriferoides. C

Anthozoa:

152 Streptelasma rectum. c

j. The middle Trilobite bed.

The fauna of this bed is much like that of the first, showing a return of the fauna with the return of the physical conditions.

Crustacea:

1 Phacops rana. cc
2 Cryphæus Boothi. c
2a C. Boothi var. calliteles. r
3 Homalonotus Dekayi. R
6 Primitiopsis punctulifera. r
Other Ostracoda.

Cephalopoda:

10 Orthoceras nuntium. r

Pteropoda:

15 Styliolina fissurella. r

Gasteropoda:

19 Platyceras carinatum. r

Lamellibranchiata:

34 Aviculopecten princeps. r
47 Modiomorpha subalata. c
55 Palæoneilo tenuistriata. r
57 P. muta. r

Brachiopoda:

79 Pholidops Hamiltoniæ. r
82 Rhipidomella Vanuxemi. r
87 Orthothetes arctostriata. r
91 Stropheodonta perplana. r
92 S. inequistriata. r

93 S. nacrea. r
100 Chonetes lepida. r
103 Productella spinulicosta. r
105 Spirifer mucronatus. r
116 Ambocœlia umbonata. r
128 Camarotœchia Sappho. R
Cryptonella sp. R

Towards the top all the fossils become rare, though the rock continues the same in lithologic character.

k. The upper Trilobite bed.

This is mucn like the preceding beds, differing from them mainly in being somewhat more shaly. It contains the following association of species:

Crustacea:

1 Phacops rana. c
2 Cryphæus Boothi. r
6 Primitiopsis punctulifera. r

Caphalopoda:

10 Orthoceras nuntium. rc

Pteropoda:

14 Tentaculites gracilistriatus. r
15 Styliolina fissurella. r

Brachiopoda:

100 Chonetes lepida. c
105 Spirifer mucronatus. rc
116 Ambocœlia umbonata. r

The association of fossils in this bed does not differ materially from that of the middle bed, except in that fewer species are present.

l. Shale and limestone six feet.

In these beds the fossils, while rare, still indicate the conditions of the Trilobite beds. The following are the observed species:

Crustacea:

1 Phacops rana. rc
6 Primitiopsis punctulifera. r

Lamellibranchiata:

34 Aviculopecten princeps. r
47 Modiomorpha subalata. r

Brachiopoda;

100 Chonetes lepida. c
105 Spirifer mucronatus. c

m. A bed of limestone, one foot.

This bed is about thirty-two feet below the Encrinal limestone, and wherever exposed forms a prominent band in the cliff. Its chief fossil is *Spirifer mucronatus.* In general the fossils are of the same species as those in the shales below. Fish remains have been found in it.

Above this limestone occur:

n. Seven feet of fissile shale with occasional bands of limestone. Fossils are not very abundant, the following having been found:

Crustacea;

1 Phacops rana. r
2 Cryphæus Boothi. R
6 Primitiopsis punctulifera. r

Brachiopoda:

99 Chonetes scitula. rc
100 C. lepida. rc
105 Spirifer mucronatus. rc
131 Liorhynchus multicostus. r

o. The Modiomorpha subalata bed.

This is a thin but continuous limestone bed, found in all the exposures, and contains an abundance of *Modiomorpha subalata.*

The complete list of fossils found is as follows:

Crustacea:

1 Phacops rana. rc
2 Cryphæus Boothi. r
6 Primitiopsis punctulifera. r

Caphalopoda:

12 Orthoceras exile. (?) R

Pteropoda:

15 Styliolina fissurella. r

Lamellibranchiata:

47 Modiomorpha subalata. C

50 Cypricardella bellistriata. r

55 Palæoneilo tenuistriata. r

58 P. emarginata. r

65 Pholadella radiata. r

67 Modiella pygmæa. R

Brachiopoda:

71 Lingula Delia. r

74 Orbiculoidea media. R

82 Rhipidomella Vanuxemi. r

93 Stropheodonta nacrea. r

100 Chonetes lepida. rc

103 Productella spinulicosta. r

105 Spirifer mucronatus. r

116 Ambocœlia umbonata. r

121 Athyris spiriferoides. rc

131 Liorhynchus multicostus. c

In the sixteen feet of shale succeeding this bed, the fossils are evenly distributed. The rock is an evenly laminated shale, and there are present several tiers of concretions. One of these, about twenty feet below the Encrinal limestone, contains *Athyris spiriferoides* and *Spirifer mucronatus* in considerable abundance.

The association of fossils gradually changes towards the top. In the four feet overlying the Modiomorpha bed the following association occurs:

p. Four feet of shale.

Crustacea:

1 Phacops rana. r

6 Primitiopsis punctulifera. r

Lamellibranchiata:

46 Modiomorpha concentrica. (?) R

55 Palæoneilo tenuistriata. rc

58 P. emarginata. rc

Brachiopoda:

79 Pholidops Hamiltoniæ. rc
82 Rhipidomella Vanuxemi. r
87 Orthothetes arctostriata. rc
91 Stropheodonta perplana. rc
99 Chonetes scitula. rc
100 C. lepida. rc
103 Productella spinulicosta. rc
105 Spirifer mucronatus. c
118 Ambocœlia spinosa. rc
131 Liorhynchus multicostus. c

Anthozoa:

152 Streptelasma rectum. r

After this *Chonetes lepida* becomes very abundant, forming a characteristic constituent of the fauna. The following is the list of fossils occurring throughout the remainder of these shales.

q. Twelve feet of fissile shale.

Crustacea:

1 Phacops rana. c
2 Cryphæus Boothi. c
6 Primitiopsis punctulifera. rc

Cephalopoda:

12 Orthoceras exile. (?) R

Pteropoda:

13 Tentaculites bellulus. r
15 Styliolina fissurella. c

Lamellibranchiata: (Most of these occur about ten feet below the Encrinal limestone.)

34 Aviculopecten princeps. r
35 A. exacutus. r
36 Pterinopecten conspectus. r
40 Pterinea flabella. r
47 Modiomorpha subalata. r
50 Cypricardella bellistriata. r
54 Palæoneilo constricta. R

55 P. tenuistriata. r
56 P. fecunda. rc
57 P. muta r
58 P. emarginata. rc
59 Macrodon Hamiltoniæ. R
60 Grammysia (arcuata?). R
61 Grammysia. sp. R
64 Lunulicardium fragile. R
65 Pholadella radiata. r

Brachiopoda:

70 Lingula Leana. rc
71 L. Delia. r
72 L. spatulata. rc
74 Orbiculoidea media. R
78 Craniella Hamiltoniæ. r
79 Pholidops Hamiltoniæ. c
82 Rhipidomella Vanuxemi. r
87 Orthothetes arctostriata. c
88 O. perversa. r
91 Stropheodonta perplana. c
98 Chonetes setigera. r
99 C. scitula. C
100 C. lepida. C
103 Productella spinulicosta. rc
105 Spirifer mucronatus. C
116 Ambocœlia umbonata. C (This is most abundant in the upper half.)
118 A. spinosa. rc
119 Cyrtina Hamiltonensis. R
121 Athyris spiriferoides. c
128 Camarotœchia Sappho. c
131 Liorhynchus multicostus. C (This is most abundant in the lower half.)
131 L. multicostus, small var. r
133 L. dubius. r
138 Tropidoleptus carinatus. r

Bryozoa:

148 Fenestella sp. and other Bryozoa. rc

Anthozoa.

152 Streptelasma rectum. r
161 Monotrypa fruticosa. r
Aulopora sp. r

In the lower half *Liorhynchus multicostus* is extremely abundant while in the upper half *Ambocœlia umbonata* predominates. *Spirifer mucronatus* and *Chonetes lepida* are equally abundant throughout. This might be considered the normal *S. mucronatus* fauna.

r. The Athyris spiriferoides bed.

This is a bed of calcareous concretions, quite continuous and about a foot in thickness. In it *Athyris spiriferoides* is extremely abundant and well preserved. The other fossils are rare, and are mainly found in the shale in which the concretions are embedded. The bed is nine feet below the Encrinal limestone. The following is the list of fossils:

Crustacea:

6 Primitiopsis punctulifera. r

Pteropoda:

13 Tentaculites bellulus. r

Lamellibranchiata:

55 Palæoneilo tenuistriata. r
56 P. fecunda. rc
58 P. emarginata. r

Brachiopoda:

79 Pholidops Hamiltoniæ. r
82 Rhipidomella Vanuxemi. r
91 Stropheodonta perplana. r
99 Chonetes scitula. r
100 C. lepida. r
116 Ambocœlia umbonata. r
120 Nucleospira concinna. r
121 Athyris spiriferoides. C

Bryozoa:

141 Stictopora incisurata. r

Anthozoa:

162 Aulopora serpens. r

Above this bed the number of species and of specimens gradually decreases, the association in the shale for two or three feet above the *A. spiriferoides* bed being as follows:

s. Dark bluish shales.

Crustacea:

6 Primitiopsis punctulifera. rc

Pteropoda:

13 Tentaculites bellulus. r
15 Styliolina fissurella. rc

Lamellibranchiata:

35 Aviculopecten exacutus. r
36 Pterinopecten conspectus. r
56 Palæoneilo fecunda. r
58 P. emarginata. rc

Brachiopoda:

70 Lingula Leana. r
79 Pholidops Hamiltoniæ. rc
82 Rhipidomella Vanuxemi. r
87 Orthothetes arctostriata. rc
91 Stropheodonta perplana. r
100 Chonetes lepida. rc
103 Productella spinulicosta. r
105 Spirifer mucronatus. r
116 Ambocœlia umbonata. r
118 A. spinosa. r
121 Athyris spiriferoides. r
124 Atrypa reticularis. r

Gradually more and more of the species disappear and others become exceedingly rare. At five feet below the Encrinal limestone the association of fossils is as follows:

t. Fissile shale.

Crustacea:

1 Phacops rana. r
6 Primitiopsis punctulifera. rc

Pteropoda:

15 Styliolina fissurella. rc

Brachiopoda:

82 Rhipidomella Vanuxemi. r
88 Orthothetes arctostriata. rc
91 Stropheodonta perplana. r
100 Chonetes lepida. rc
105 Spirifer mucronatus. rc
119 Cyrtina Hamiltonensis. R
131 Liorhynchus multicostus. r

The change thus, is in the disappearance of species, the three additional forms observed (1, 119 and 131) probably occurring in the shale beneath. After this the shale becomes finer and less perfectly laminated, and the fossils become rarer and rarer, until at four feet from the Encrinal limestone (in the sections examined) it is practically barren, save for an extreme development of *Styliolina fissurella.* Some thin layers seem to be filled with it, and with *Tentaculites gracilistriatus. Primitiopsis puuctulifera* is also common. Of the larger fossils, however, scarcely any trace is found. Extended search gave the following list:

u. Fine, dark and poorly laminated shale.

Crustacea:

6 Primitiopsis punctulifera. c

Pteropoda:

14 Tentaculites gracilistriatus. C
15 Styliolina fissurella. C

Lamellibranchiata:

51 Nuculites oblongatus. R

Brachiopoda:

79 Pholidops Hamiltoniæ. R
87 Orthothetes arctostriata. R
100 Chonetes lepida. R
138 Tropidoleptus carinatus. R

This change is probably a local one, affecting the region immediately about Eighteen Mile creek and indicating a local change in currents and sediment.

v. As the shale becomes more calcareous again, the normal fauna (q) returns, and at three feet below the Encrinal limestone becomes fully established once more. Some of the species however did not return, or at least not until the *S. demissa* subfauna became fully established. These are numbers: 2, 13, 15, 34, 35, 50, 59, 64, 65, 70, 71, 72, 74, 78, 79, 88, 103, 116, 118, 131, 133, 138, 148 and 161, of the list given under (q). The following new forms characteristic and suggestive of the S. demissa subfauna appear:

66 Cypricardinia indenta. R
89 Stropheodonta demissa (upper part). R
101 Chonetes coronata. r
109 Spirifer granulosus. r
110 S. audaculus. rc
115 S. subumbonus. r
120 Nucleospira concinna. r
124 Atrypa reticularis. rc

Stictopora incisurata also reappears in considerable numbers.

Stropheodonta demissa appears for the first time in these strata, and immediately above becomes the dominant form.

w. The Stropheodonta demissa bed.

This bed is calcareo-argillaceous, in places forming a solid mass mainly composed of organic remains. *Stropheodonta demissa* is the most characteristic form, while in many respects the fauna is a return of that characteristic of the middle and upper Pleurodictyum beds and the shales enclosing them.

The list of observed species is as follows:

Crustacea:

†1 Phacops rana. c
†6 Primitiopsis punctulifera. r

Pteropoda:

13 Tentaculites bellulus. r
14 T. gracilistriatus. r
†16 Coleolus (?) gracilis. R

Gasteropoda:

*18 Platyceras erectum. r
19 P. carinatum. rc

†20 P. Thetis. r
23 P. (Orthonychia) attenuatum. r
†24 Platyostoma (Diaphorostoma) lineata. c

Lamellibranchiata:

†34 Aviculopecten princeps. rc
35 A. exacutus. rc
†36 Pterinopecten conspectus. rc
*38 P. undosus. (?) r
*39 P. sp. R
†40 Pterinea flabella. c
†41 Actinopteria decussata. r
43 Leiopteria Rafinesquii. R
44 L. sp. R
†54 Palæoneilo constricta. R
56 P. fecunda. rc
†57 P. muta. r
†58 P. emarginata. rc
*62 Sphenotus truncatus. R
†66 Cypricardinia indenta. C

Brachiopoda:

72 Lingula spatulata. r
*73 Lingula sp. R
†76 Orbiculoidea Lodensis. R
†78 Craniella Hamiltoniæ. r
79 Pholidops Hamiltoniæ. rc
*80 P. linguloides. r
†82 Rhipidomella Vanuxemi (small). c
†84 R. Penelope (small). r
†87 Orthotetes arctostriata. c
†88 O. perversa. r
89 Stropheodonta demissa. C
†90 S. concava. C
†91 S. perplana. c
†92 S. inequistriata. C
*94 S junia. r
*95 S. plicata. r
†99 Chonetes scitula. c

†100 C. lepida. rc
†101 C. coronata. rc
†103 Productella spinulicosta. rc
†105 Spirifer mucronatus. C
†109 S. granulosus. c
†110 S. audaculus. c
*111 S. angustus. r
†112 S. macronotus. rc
*113 S. asper. rc
†114 S. fimbriatus. C
†116 Ambocœlia umbonata. r
†119 Cyrtina Hamiltonensis. c
†120 Nucleospira concinna. c
†121 Athyris spiriferoides. r
124 Atrypa reticularis. c
†128 Camarotœchia Sappho. r
†135 Cryptonella planirostra. r

Crinoidea:

*140 Ancyrocrinus bulbosus. r

Bryozoa:

†141 Stictopora incisurata. c
*143 Tæniopora exigua. R
*145 Reptaria stolonifera. R
*146 Loculipora perforata. c
*147 Fenestella emaciata. c
†148 Fenestella sp. c

Anthozoa:

*149 Favosites argus. R
†152 Streptelasma rectum. c
*155 Heliophyllum Halli. R
*158 Cystiphyllum conifollis. r
†161 Monotrypa fruticosa. r
162 Aulopora serpens. r

The species marked (*) occur for the first time in these shales. Those marked (†) are found in the middle and upper Pleurodictyum beds, and the enclosing shales, as far as the base of the Trilobite beds. The similarity

between the early and late Hamilton fauna is thus apparent. The introduction of the western species, *Spirifer asper* and *Stropheodonta plicata*, gives an added interest to this bed. Its total thickness is not much over four inches, the seventy-two species which it contains being crowded within that narrow vertical range. Overlying it are several inches of almost barren shale, which are followed by:

x. The Stictopora bed.

In this bed, which is often less than an inch in thickness, *Stictopora incisurata* and *Nucleospira concinna* are extremely abundant, the rock often being made up of the cemented fragments of the former, and shells of the latter with crinoid joints. Weathering separates them from the rock, and they may be picked up in great numbers and in a fine state of preservation.

Stropheodonta demissa has almost disappeared, only two or three fragments having been obtained from this bed.

The following are its fossils:

Crustacea:

1 Phacops rana. c
2 Cryphæus Boothi. r

Pteropoda;

13 Tentaculites bellulus. r

Gasteropoda;

20 Platyceras Thetis. rc
23 P. (Orthonychia) attenuatum. rc
24 Platystoma (Diaphorostoma) lineata. c

Lamellibranchiata:

35 Aviculopecten exacutus. r
40 Pterinea flabella. r
41 Actinopteria decussata. rc
57 Palæoneilo muta. r
66 Cypricardinia indenta. c

Brachiopoda:

78 Craniella Hamiltoniæ. r
79 Pholidops Hamiltoniæ. r
82 Rhipidomella Vanuxemi (small). c
84 R. Penelope (small). r

87 Orthothetes arctostriata r
88 O. perversa r
89 Stropheodonta demissa. R
91 S. perplana. rc
92 S. inequistriata. rc
99 Chonetes scitula. r
100 C. lepida. r
101 C. coronata. r
103 Productella spinulicosta. c
105 Spirifer mucronatus. C
110 S. audaculus. c
112 S. macronotus. c
114 S. fimbriatus. rc
116 Ambocœlia umbonata. r
119 Cyrtina Hamiltonensis. c
120 Nucleospira concinna. C
121 Athyris spiriferoides. r
124 Atrypa reticularis. r
127 Camarotœchia Horsfordi. r

Bryozoa:

141 Stictopora incisurata. C
143 Tæniopora exigua. r
148 Fenestella sp. c

Anthozoa:

152 Streptelasma rectum. r

The shale above this is usually barren, *Stictopora incisurata* occasionally occurring, while the upper few inches are devoid of fossils and calcareous material in general as already noted.

C. The fauna of the Encrinal limestone or the *Spirifer sculptilis* fauna.

The Encrinal limestone contains a distinct association of fossils, many of which are not found outside of it. In this region *Spirifer sculptilis* is entirely confined to it, *S. mucronatus* being scarcely represented. *S. sculptilis* is therefore chosen as the characteristic form, though it is by no means the most abundant *Spirifer* in this rock. Many of the species which are only sparingly represented in the Lower shales are here abundant. Such are *Tropidoleptus carinatus* and *Rhipidomella Vanuxemi*. In general most of the

fossils are found only in the upper part of the limestone, where it is of a less compact character. The corals however are mainly found in the lower part of the rock.

The following is the list:

Crustacea:

*1 Phacops rana. c
*2 Cryphæus Boothi. r
2a C. Boothi var. calliteles (?) R
†4 Proetus macrocephalus. R

Cephalopoda:

*9 Orthoceras subulatum. R
†11 O. Telamon. r

Gasteropoda:

19 Platyceras carinatum. rc
†21 P. bucculentum. R
23 P. (Orthonychia) attenuatum. rc
*24 Platyostoma (Diaphorostoma) lineata. rc
25 Euomphalus laxus. R
†26 E. rudis. R
†27 Pleurotomaria Lucina. R

Lamillibranchiata:

34 Aviculopecten princeps. rc
41 Actinopteria decussata. rc
Lyriopecten orbiculatus.
†45 Mytilarca (Plethomytilus) oviformis. c
46 Modiomorpha concentrica. c
†49 Goniophora modiomorphoides. c
50 Cypricardella bellistriata. R
†63 Conocardium sp. r

Brachiopoda:

80 Pholidops linguloides. r
†81 P. oblata (?). r
*82 Rhipidomella Vanuxemi. C
83 R. leucosia. r
84 R. Penelope. c
*85 R. idoneus. r
89 Stropheodonta demissa. R

90 S. concava. R
*91 S. perplana. rc
*92 S. inequistriata. r
93 S. nacrea. rc
*96 Chonetes mucronata. r
*97 C. deflecta. r
*99 C. scitula. r
101 C. coronata. rc
†102 Productella navicella. r
*103 P. spinulicosta. r
*105 Spirifer mucronatus. R
†107 S. sculptilis. rc
109 S. granulosus. C
*110 S. audaculus. rc
112 S. macronotus. c
114 S. fimbriatus. rc
*116 Ambocœlia umbonata. r
*120 Nucleospira concinna. R
*121 Athyris spiriferoides. rc
†122 Meristella Haskinsi. r
†123 M. rostrata. R
†126 Vitulina pustulosa. c
*127 Camarotœchia Horsfordi. r
128 C. Sappho. rc
129 C. Dotis. r
†130 C. sp. R
†134 Centronella impressa. c
135 Cryptonella planirostra. c
138 Tropidoleptus carinatus. C

Bryozoa:

141 Stictopora incisurata. r

Anthozoa:

†150 Favosites Hamiltoniæ. C
†*154 Zaphrentis simplex. R
*155 Heliophyllum Halli. r
†156 H. confluens. r
†163 Craspedophyllum subcæspitosum. r

The twenty species marked (†) occur for the first time in this region. Those marked (*) pass upwards into the lower Moscow shale Nineteen species therefore are entirely restricted to the Encrinal limestone. In addition to these the following are characteristic of this rock:

Phacops rana, Modiomorpha concentrica, Rhipidomella Vanuxemi, Stropheodonta nacrea, Spirifer granulosus, S. macronotus, Cryptonella planirostra and Tropidoleptus carinatus.

D. The fauna of the Lower Moscow shale or the *Spirifer consobrinus* fauna.

This fauna is characterized by the abundant development of *S. consobrinus* D'Orb., which has entirely replaced *S. mucronatus*. This latter form is extremely rare, only a few poorly preserved specimens having been obtained. The fauna occupies the lower four or five feet of the shale, after which fossils become rare. *S. consobrinus* is not found outside of this horizon, but characterizes it wherever examined. The fauna admits of subdivision into several groups as follows;

a. The lower foot and three-quarters of shale, poorly laminated and weathering into a tenacious clay, contains;

Crustacea;

1 Phacops rana. rc
2 Cryphæus Boothi. r

Lamellibranchiata:

55 Palæoneilo tenuistriata. R
56 P. fecunda. r
57 P. muta. rc
66 Cypricardinia indenta. R

Brachiopoda;

79 Pholidops Hamiltoniæ. c
91 Stropheodonta perplana. c
97 Chonetes deflecta. rc
99 C. scitula. r
100 C. lepida. r
108 Spirifer consobrinus. rc
116 Ambocœlia umbonata. C
121 Athyris spiriferoides. rc

Anthozoa:

152 Streptelasma rectum. C

In many places *Ambocœlia umbonata* occurs in vast numbers especially in the beds immediately above the Encrinal limestone.

b. Coral layer, three inches.

This bed has been traced for about two miles, and throughout contains the same association of corals and brachiopods. It is the only bed in which the larger cup corals, especially *Heliophyllum Halli* are at all abundant, a single specimen only of the latter having been found outside of this bed at Eighteen-Mile creek. This is also, with one exception, the only level at which *Atrypa aspera* is found in this region.

A. reticularis is also more abundant, robust, and characteristic than in any other bed. *Cystiphylli* of various species make up the main portion of the bed. Nearly all the corals lie upon their sides, in some cases two or even three and four lying on top of each other. A large specimen of *Heliophyllum Halli* which had fallen over, and grown up again, so as to bend at right angles, had again fallen and lay upon one side. A branch, long since broken off, had grown upwards from the angle. The side on which the coral lay was encrusted with Bryozoa, *Aulopora*, and a species of *Crania*. Only three corals were seen standing upright, while as many more were completely inverted. The corals do not show any evidence of wear, the delicate organic incrustations retaining their normal perfection. Wherever the corals are scarce, *Atrypa aspera*, *A. reticularis* and other brachiopods are abundant. The first is very common, but a few specimens only show the spines. In this respect the specimens strongly contrast with those found at Moscow, N. Y., where nearly all the specimens retain their spines.

The following is a list of the fossils obtained from this bed:

Brachiopoda:

Crania (?). rr

110 Spirifer audaculus var. Eatoni. rc

124 Atrypa reticularis. c.

125 A. aspera. C

Bryozoa:

Several species.

Anthozoa:

154 Zaphrentis simplex. rc
155 Heliophyllum Halli. c
157 Cystiphyllum Americanum. rc
158 Cystiphyllum conifollis. C
Aulopora. r

Streptelasma rectum is abundant above and below this bed, but it has not been found in the bed itself.

Above the coral bed, *Ambocoelia umbonata* becomes less abundant, and *Chonetes deflecta* and *C. mucronata* increase in number. *Spirifer consobrinus* also becomes more numerous.

c. One foot of shale, calcareous and unevenly laminated.

It contains:

Crustacea:

1 Phacops rana. c

Lamellibranchiata:

55 Palæoneilo tenuistriata. c
56 P. fecunda. rc

Brachiopoda:

78 Craniella Hamiltoniæ. r
79 Phollidops Hamiltoniæ. r
91 Stropheodonta perplana. rc
96 Chonetes mucronata. c
97 C. deflecta. C
100 C. lepida. r
105 Spirifer mucronatus. R
108 S. consobrinus. c
110 S. audaculus. rc
116 Ambocœlia umbonata. c
119 Cyrtina Hamiltonensis. R
121 Athyris spiriferoides. r
127 Camarotœchia Horsfordi. r
131 Liorhynchus multicostus. r

Anthozoa;

152 Streptelasma rectum. rc

d. Two feet of shale less calcareous than c; unevenly laminated. *Ambocœlia umbonata* has practically disappeared, while *Atrypa reticularis, Streptelasma rectum* and *Cystiphyllum* have become abundant.

Crustacea;

1 Phacops rana. rc.

2 Cryphæus Boothi. r

Gasteropoda:

Platyceras sp. R

24 Platyostoma lineata. r

Lamellibranchiata:

36 Pterinopecten conspectus. r

Brachiopoda:

82 Rhipidomella Vanuxemi. r

85 R. idoneus. R

87 Orthothetes arctostriata. r

92 Stropheodonta inequistriata. rc

96 Chonetes mucronata. r

97 C. deflecta. r

120 Nucleospira concinna. r

121 Athyris spiriferoides. r

124 Atrypa recticularis. c

125 A. aspera. R

Crinoidea:

139 Taxocrinus sp. R

140 Ancyrocrinus bulbosus and undetermined species. r

Anthozoa:

152 Streptelasma rectum. c

153 S. ungula. r

158 Cystiphyllum conifollis. c

159 Amplexus Hamiltoniæ. rc

160 A. (?) intermittens. r

161 Monotrypa fruticosa. rc

Above these beds fossils become more and more scarce, *Phacops rana* alone remaining; this finally disappears and the shale is practically barren for about eight feet wherever examined. At Section E, in Eighteen-mile

creek, a thin bed crowded with *Orbiculoidea media* occurs seven or eight feet above the base of the Moscow shale. Associated with this species are *O. Doria* (?), *Schizobolus truncatus*, both rare, and a few impressions of *Spirifer mucronatus*. *Schizobolus truncatus* occurs for the first time in this region, and indicates the approach of the Genesee fauna.

E. The fauna of the upper Moscow shale, or the *Spirifer tullius* fauna.

This fauna occupies the upper four feet of the Moscow shales. The fauna of the upper foot differs from the normal fauna in its more transitional character, and in the absence of *S. tullius*. It is therefore separated as a distinct subfauna.

The normal fauna.

The most characteristic form of the normal fauna is *Spirifer tullius*, which has not been found outside of these beds. The specimens are all dwarfed representatives of the larger eastern forms, but otherwise show the characters well. At first the species is rare, or practically absent, but near the middle of the beds it becomes quite abundant. *Ambocœlia præumbona* makes its first appearance, and is represented by numerous and large specimens; *A. umbonata* has practically disappeared.

a. At the beginning of this fauna only the following species occur (all brachiopoda):

77 Schizobolus truncatus. R
87 Orthothetes arctostriata. r
103 Productella spinulicosta. rc
106 Spirifer tullius. r
116 Ambocœlia umbonata. R
117 A. præumbona. c

b. The normal association of species in the *S. tullius* fauna is as follows:

Crustacea:

1 Phacops rana. r

Cephalopoda:

9 Orthoceras subulatum. R

Pteropoda:

13 Tentaculites bellulus. (?) R
14 T. gracilistriatus. r
Tentaculites sp. rr

Brachiopoda:

77 Schizobolus truncatus. r
87 Orthothetes arctostriata. r
96 Chonetes mucronata. r
99 C. scitula. r
100 C. lepida. r
105 Spirifer mucronatus. R
106 S. tullius. c
115 S. subumbonus. r
116 Ambocœlia umbonata. R
117 A. præumbona. C
118 A. spinosa. r
121 Athyris spiriferoides. r
131 Liorhynchus multicostus. r

c. Transition shales.

116 Ambocœlia umbonata (small). R
117 A. præumbona. C
118 A. spinosa. r
121 Athyris spiriferoides. r
131 Liorhynchus multicostus (small). r

Annelida:

Conodonts — found only in the shale immediately beneath the concretionary limestone layer of Section H. rc

This is the last of the true Hamilton faunas, and even in this and the preceding, the presence of *Schizobolus truncatus* indicates a certain transitional character. This becomes strongly expressed in the fauna of the upper foot of shale and limestone, which is here regarded as purely transitional.

b. The Transition or Schizobolus fauna.

Between this and the preceding, there is usually a bed of more or less continuous calcareous concretions. In Section H, at Eighteen-mile creek, the characteristic fossils occur in a concretionary argillaceous limestone, which immediately underlies the Conodont bed. The fauna is marked by the extreme development of the three species *Schizobolus truncatus*, *Ambocœlia præumbona* and *Liorhynchus multicostus*. Other fossils are very rare.

The complete list of the fossils obtained from this bed is as follows:

Cephalopoda:

Orthoceras sp. R

Pteropoda:

14 Tentaculites gracilistriatus. rc
15 Styliolina fissurella. rc

Brachiopoda:

74 Orbiculoidea media. r
77 Schizobolus truncatus. C
87 Orthothetes arctostriata. R
100 Chonetes lepida. r
115 Spirifer subumbonus. r
116 Ambocœlia umbonata (small) R
117 A. præumbona. C
121 Athyris spiriferoides. R
131 Liorhynchus multicostus. C
L. quadricostatus. (?) R

The relation of this fauna to the normal *Spirifer tullius* fauna is apparent, differing from this only in the greater development of *Schizobolus truncatus* and *Ambocœlia præumbona.*

There are, then, a number of quite distinct faunas in the Hamilton group of Western New York. These are:

F. The Spirifer tullius fauna (including the Schizobolus fauna).
E. The Spirifer consobrinus fauna.
D. The Spirifer sculptilis fauna.
C. The Spirifer mucronatus fauna.

None of the characteristic Spirifers with the exception of *S. mucronatus* occurs outside of its proper fauna and this exception is an extremely rare one.

Underlying these faunas are:

B The transition fauna of the upper Marcellus.
A The Marcellus faunas.

The "Conodont" bed and its fauna.

Immediately overlying the limestone layer which contains the Schizobolus fauna at Section II, Eighteen-mile creek, are about two inches of grey shale

having a greasy feel. This shale is unevenly laminated, somewhat fissile, and contains no fossils whatever. It is followed by a thin band of semi-bituminous shale approaching a shaly limestone. The fossils in this are *Styliolina fissurella* and *Tentaculites gracilistriatus* with an occasional flattened spore. This is followed by the Conodont bed described by Hinde, nowhere over three inches thick. The rock is mainly made up of the joints of crinoid stems, and of fish remains. Conodonts are plentiful. The following forms have been described from this bed.*

†Prioniodus erraticus Hinde.
P. abbreviatus, H.
P. clavatus, H.
‡P. Panderi, H.
P. (?) oblatus, H.
‡Polygnathus princeps, H.
‖P. solidus, H.
P. crassus, H.
‖P. pennatus, H.
‖P. tuberculatus, H.
‖P. cristatus, H.
‡P. truncatus, H.
‡P. linguiformis, H.
P. (?) simplex, H.

The first of these was also noted by Clarke in the Naples beds. (See Bull. 16 U. S. Geol. Surv.)

A single specimen of *Lingula spatulata* and one of *Liorhynchus quadricostatus* was obtained from this rock. Occasional specimens of (?) *Ambocœlia præumbona* still occur, showing that the Hamilton conditions have not quite passed away. As a whole, however, the affinities of the fauna of this rock are with that of the Genesee, both the "Conodonts" and the numerous fish scales and plates pointing strongly to this conclusion. There seems to have been no adequate reason why Hinde should refer this bed to the Hamilton instead of the Genesee, more especially as it is so closely united with the overlying Styliolina limestone in many places, and often contains what might be called concretionary masses of this rock, i. e., small masses of rock composed of *Styliolina fissurella*.

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* Quart. Journ. Geol. Soc. 1879, p. 359.

† Also recorded from the Cleveland shales and from the Corniferous of Ohio.

‡ Also recorded from the Genesee shale.

‖ Also identified by Clarke in the black shales of the Naples beds (Sixth Ann. Rep. State Geol. 1887, pp, 30–32, pl. i).

IV. COMPARISON OF THE FAUNAS OF THE HAMILTON GROUP AT EIGHTEEN-MILE CREEK WITH THE RECORDED FAUNAS OF THAT GROUP AT OTHER LOCALITIES.

In 1888, Professor Samuel Calvin* described the vertical range of certain species of fossils of the Hamilton period, in the region about Widder (Thedford), Arkona, and Bartletts Mills, Ontario, one hundred and thirty miles west of Eighteen-mile creek. In a section two hundred or two hundred and fifty feet thick he made three distinct subdivisions, based on palaeontologic evidence. The lower division exposed below Bartletts Mills and near Arkona is characterized by the predominance of *Spirifer mucronatus*, Conrad, of the ordinary extended form with comparatively flat valves and many plications. This is essentially the form which I have noted in the foregoing pages as characteristic of the Lower Shales of the Eighteen-mile creek region, or the type form of my *Spirifer mucronatus* fauna. Associated with this species, on the Ontario Hamilton is *Chonetes lineatus*, Conr. which in the beds about Eighteen-mile creek is represented by *C. scitula*. *Phacops rana* occurs in both.

In their principal species the beds agree at the two localities, and may be regarded as equivalent.

The third division, namely, that exposed at Widder, is characterized by the thick short form of *S. mucronatus* with few plications, well known as characteristic of that locality. I have before me a number of the Widder specimens, and on comparing them with specimens of *S. consobrinus* from Eighteen-mile creek, I can find few points of difference in the external characters. The most important difference is the greater height and more arcuate character of the hinge area of *S. consobrinus*, and the somewhat greater regularity and prominence of its zigzag striae. But it might be questioned whether these differences are not such as would come from development of the same species in widely separated localities.

The following species are recorded as associated with this *S. mucronatus* at Widder:

Cyrtia (=Cyrtina) Hamiltonensis.
Athyris spiriferoides (small form).
(?) Liorhynchus multicostus.

* Am. Geol. Vol. I, p. 81, *et seq.*

Chonetes scitula.
Stropheodonta nacrea.
Callopora (=Fistulopora) incrassata.

All of these except the last two species occur in the typical *Spirifer consobrinus* fauna of the Eighteen-mile creek region, and *S. nacrea* occurs in the limestone immediately below. *Fistulipora incrassata* has not been noticed. The *S. consobrinus* fauna of the Eighteen-mile creek region then corresponds in a general way to the upper (Widder) division of the Ontario Hamilton.

The "middle division" of Professor Calvin is characterized by the great development of corals, of which *Heliophyllum Halli* is the abundant and characteristic form. With it occur the following:

Cystiphyllum Americanum
Heliophyllum juvene.
Diphyphyllum (=Craspedophyllum) Archiaci.
Several species of Favosites.
Several species of Alveolites, and a number of others.

Spirifer fimbriatus and *Atrypa reticularis* also occur. This fauna ceases abruptly and the upper fauna appears as abruptly.

That this "middle fauna" bears some relation to the Encrinal limestone fauna of the Eighteen-mile creek region, seems evident. At Morse creek, the lower Encrinal contains many corals, and at Eighteen-mile creek these and especially *Favosites*, form a characteristic constituent of the fauna. The corals do not disappear as abruptly as they do in Canada, but recur in the lower part of the *S. consobrinus* fauna. There is thus indicated a uniformity of conditions and similarity of changes over an extensive area.

At Livonia, N. Y., in the Genesee valley, the Hamilton has a total thickness of 517 feet*; 280 feet of this represents the Upper shale, two feet the Encrinal limestone, and 235 feet the Lower shale. The four feet of sandy shale and calcareous layer immediately below the limestone are united with it into the "Encrinal band."

In order that a comparison between the Livonia section and the Eighteen-mile creek section can be made, it is important that the reference plane here chosen, i. e. the Encrinal limestone or band, is equivalent in the two places. Such equivalency can of course only be determined by their fossils, the mere occurrence of a two-foot stratum of limestone in both localities being of little significance for purposes of correlation. Comparing the fossils of the two limestone beds, we find only one of the species given in the Livonia list

* D. D. Luther, Report. N. Y. State Geol. 1893.

(which is probably incomplete as far as the rarer species are concerned) wanting in the limestone at Eighteen-mile creek, this being *Lyriopecten suborbicularis* (=*L. orbiculatus*)! (which has been recorded from Eighteen-mile creek).

Of the fossils recorded from the rock from five feet above to four feet below the Encrinal limestone, the following species do not occur in the Encrinal of Eighteen-mile creek: a. *Bellerophon leda.* b. *Pleurotomaria Itys.* c. *Cypricardinia identa.* d. *Palæoneilo fecunda.* e. *Spirifer divaricatus.* f. *Atrypa reticularis.* g. *Polypora latitruncata.* h. *P. undulata.* i. *Orthoceras exile.* k. *O. nuntium.* l. *Pleurotomaria trilix.* m. *Modiomorpha macilenta.* n. *Liopteria greeni.* o. *Goniophora truncata.* p. *Aviculopecten exactus.* q. *Dielasma Romingeri.* r. *Crania Hamiltoniæ.* s. *Trematospira hirsuta.*

Of these a, b, k and g are known only from the lowest beds of the group at Eighteen-mile creek, while e, g, h, m, n, a and s are unknown at Eighteen-mile creek. Most of the others occur either immediately below or above the Encrinal limestone at Eighteen-mile creek.

It seems that we are thus justified in regarding the Encrinal limestone as a continuous bed throughout the western part of the State of New York, representing a uniform condition of sea bottom, purity of water, and physical conditions generally, thus favoring the dissemination of species which probably had a local origin. It also furnsshed the conditions favorable for the gradual migration of faunas, from localities which had become unfavorable to their existence to those in which their normal environment had become established.

An examination of the fauna of the Lower shales of Livonia, reveals its relation to the Marcellus fauna. This is especially true of the lower 147 feet, as noted by Luther and Clarke, in which Marcellus species predominate. In fact it seems to me, that these shales should be classed with the Marcellus, at any rate as transition beds. The eighty-four feet of shale overlying these beds, while exhibiting their Hamilton character in their fossils, nevertheless contain many species which have passed upward from the underlying shales, and are also found in the typical Marcellus shale. Eliminating these from the recorded fauna, there remain the following species, which are distributed through the eighty-four feet of shale below the Encrinal band:

Modiomorpha subalata. c
*Paracyclas lineatus. rc
Aviculopecten princeps. rc
Palæoneilo fecunda. rc

*Lunulicardium Livoniæ. rc
*Panenka retusa. rc
*Phthonia nodocostata. rc
Ambocœlia umbonata. c
Spirifer mucronatus (small). c
Liorhynchus multicostus. c
Productella spinulicosta. c
Orbiculoidea media. c
Stropheodonta perplana. r

Those starred do not occur in the Eighteen-mile creek region, while some of the others are especially abundant in the lower part of the lower shales at Eighteen-mile creek. A comparison of the lists of species from the lower shales of these two localities at once reveals the greater abundance in species and individuals, of fossils at Eighteen-mile creek, indicating favorable conditions which however ceased after the Encrinal limestone was deposited. The complete extinction of many species before the beginning of the *Spirifer consobrinus* fauna at Eighteen-mile creek, is remarkable, but what is equally remarkable is that many of these species appear at Livonia in the Upper shales where they make their first appearance in that region. *Spirifer granulosus*, unknown in the Moscow shales of the Eighteen-mile creek, but abundant in the lower and upper beds of the Lower shales and in the Encrinal limestone of that region, makes its first appearance at Livonia, seventeen or eighteen feet above the Encrinal limestone. The characteristic corals of the Encrinal limestone and the "coral layer" at Eighteen-mile creek appear five feet above the former bed at Livonia, and above them *Meristella Haskinsi* and *Spirifer sculptilis* occur abundantly. *Pleurodictyum stylopora* restricted to the Pleurodictyum beds at the base of the Lower shales at Eighteen-mile creek, makes its first appearance sixty-five feet above the Encrinal limestone at Livonia.

The following sixty-eight species of fossils common in, and frequently characteristic of, the Lower shales and the Encrinal limestone at Eighteen-mile creek and vicinity, occur for the first time and usually in abundance, in the Encrinal band and the Upper shales of the Livonia section. Those starred pass upwards into the Upper (Moscow) shales at Eighteen-mile creek, but with few exceptions are not very characteristic of them;

Crustacea:

†*1 Phacops rana.
†*2 Cryphæus Boothi.

3 Homalonotus Dekayi.
4 Proetus macrocephalus.
6 Primitiopsis punctulifera.

Cephalopoda:

*9 Orthoceras subulatum.
10 O. nuntium.

Pteropoda:

*14 Tentaculites gracilistriatus.

Gasteropoda:

20 Platyceras Thetis.
21 P. bucculentum.
22 P. symmetricum.
23 P. (Orthonychia) attenuatum.
*24 Platyostoma (Diaphorostoma) lineatum.
27 Pleurotomaria lucina.
29 P. Itys.
30 P. capillaria.
31 Loxonema Hamiltoniæ.
32 L. delphicola.
†33 Bellerophon Leda.

Lamellibranchiata:

35 Aviculopecten exacutus.
38 Pterinopecten undosus.
40 Pterinea flabella.
41 Actinopteria decussata.
45 Plethomytilus oviformis.
46 Modiomorpha concentrica.
50 Cypricardella bellistriata.
54 Palæoneilo constricta.
59 Macrodon Hamiltoniæ.
65 Pholadella radiata.
68 Tellinopsia subemarginata.

Brachiopoda:

70 Lingula leana.
71 L. Delia.
72 L. spatulata.

*78 Craniella Hamiltoniæ.
*79 Pholidops Hamiltoniæ.
*82 Rhipidomella Vanuxemi.
84 R. Penelope.
*87 Orthothetes arctostriata.
90 Stropheodonta concava.
*92 S. inequistriata.
93 S. nacrea.
94 S. junia.
†*100 Chonetes lepida.
101 C. coronata.
104 Strophalosia truncata.
†*105 Spirifer mucronatus.
107 S. sculptilis.
109 S. granulosus.
*110 S. audaculus.
114 S. fimbriatus.
*118 Ambocœlia spinosa.
*119 Cyrtina Hamiltonensis.
*120 Nucleospira concinna.
*121 Athyris spiriferoides.
122 Meristella Haskinsi.
*124 Atrypa reticularis.
135 Cryptonella planirostra.
137 Dielasma (Cranæna) Romingeri.
138 Tropidoleptus carinatus.

Bryozoa:

141 Stictopora incisurata.
143 Tæniopora exigua.
145 Reptaria stolonifera.

Anthozoa:

149 Favosites argus.
151 Pleurodictyum stylopora.
*152 Streptalasma rectum.
*155 Heliophyllum Halli.
*161 Chætetes fructicosus.
163 Craspedophyllum Archiaci.

Of those marked †, *Spirifer mucronatus* is represented in the Lower shales of Livonia by a small variety, which may have given rise to stouter and larger individuals when the conditions became more favorable. The others thus marked occur in the lower 147 feet of shale, associated with Marcellus species, but as they do not occur in the intermediate eighty feet of shale, their reappearance in the succeeding beds may be accounted for by immigration from the west.

The sequence of geological events in this region seems to have been as follows: *

After the limestone making epoch of the Corniferous period, a mud-making epoch, with shallow water and a scarcity of life began, during which the Marcellus shales were deposited. These conditions, as shown by H. S. Williams, extended westward beyond the limits of the State of New York, the black shales of Ohio and other states probably corresponding in part to the Marcellus of New York. The shallow water and unfavorable conditions are indicated by the scarcity and small size of the majority of the fossils, and by the plant remains to which the shales owe much of their bituminous character. In the Genesee Valley these conditions continued after the establishment of the Hamilton fauna and thus we can account for the scarcity of the fossils in the lower shales of that region, the preponderance of pelecypods, and the similarity of the fauna as a whole, to the Marcellus. These conditions, however, soon gave way to more favorable ones in Western New York and Ontario, allowing the development of a luxuriant fauna. To the south and southwest, the conditions remained more nearly as they were, during the Marcellus epoch of New York, and the deposition of the black shales of Ohio, Indiana, Kentucky and other states continued. Toward the close of the lower Hamilton in Western New York, a greater dispersion of the organic forms took place, owing probably to an increased subsidence eastward, and the purification of the waters by the diversion of the mud-bearing currents. At any rate a uniform condition of the sea existed at Livonia, Eighteen-mile creek, and perhaps Widder, Ontario, with waters sufficiently pure to permit the growth of corals and crinoids in profusion. That the waters were not very deep during the formation of the Encrinal limestone, is shown by the comminuted character of the organic remains especially the crinoids, indicating a certain amount of wave action. The Upper Hamilton was inaugurated by the influx of muddy waters, but the conditions now became reversed. Continued subsidence

* These generalizations are advanced tentatively, and may require modification after sections between those mentioned here are studied.

went on in the Genesee Valley, allowing there the luxuriant development of the faunas which had flourished earlier in the more western waters, and which had migrated to their new station when the conditions became uniform. At Eighteen-mile creek, however, subsidence had practically ceased, and thus, while 280 feet of calcareous mud accumulated above the Encrinal limestone in the Genesee Valley, only seventeen feet accumulated in the vicinity of Eighteen-mile creek. The shoaling of the waters in the Eighteen-mile creek region was the means of driving out the last survivors of the Lower (*Spirifer mucronatus*) and the Encrinal limestone (*S. sculptilis*) faunas, which found their normal environment farther east, in the subsiding Genesee Valley trough. While the lower Moscow, or *S. consobrinus* fauna existed at Eighteen-mile creek, the conditions about Widder, Ontario, were very similar, as proved by the similarity of the fauna. But in this latter region subsidence continued, allowing the uninterrupted existence of this fauna, while at Eighteen-mile creek owing to the continued shoaling of the water, it soon became extinct. That the shoaling of the water was at first a comparatively rapid one, seems to be indicated by the sudden overwhelming of the coral forest which had grown for some time after the Encrinal limestone bed had been formed. As already pointed out these corals lie piled one upon the other often three or four deep, and scarcely a single one remained standing. To the wave action in this region, and probably also to the maceration resulting from long exposure before burial, must be attributed the loss of the spines in most of the specimens of *Atrypa aspera*, only a very small number preserving any trace of them, while in the Genesee Valley almost every specimen shows them. The smooth water-worn pebble and the water-worn fragment of a *Spirifer granulosus* found in the lower Moscow of Eighteen-mile creek, while in themselves of little value are of interest in connection with the other proofs of shallow water in this region. *S. granulosus* as noted above does not occur in the Moscow shales of Eighteen-mile creek, but is abundant in the Encrinal of that region. The shale itself bears evidence of having accumulated in shallow water, by the presence of plant remains, and by its lithologic character.

The reversal of conditions is also shown by the occurrence in the lower Moscow of Eighteen-mile creek, at about a foot *above* the Encrinal limestone, of a bed composed almost entirely of *Ambocœlia umbonata* and by the occurrence at Livonia of a similar bed twelve feet *below* the Encrinal band. Similarly bands composed of *Liorhynchus multicostus* occur in the Lower shale at Livonia, and in the upper part of the Upper shales at Eight-

een-mile creek. These two species evidently could thrive in the shallow muddy waters. While the Hamilton conditions continued for a long time in the subsiding Genesee Valley trough, the Genesee conditions appeared in the Eighteen-mile creek region as shown by the occurrence in the barren middle "Moscow" of the *Orbiculoidea media* band with *Schizobolus truncatus*. This latter species also occurred during the existence in this region of the *S. tullius* fauna, and in the transition beds above, it becomes very prominent. That the *Styliolina* limestone was accumulated in comparatively shallow water, and does not indicate a great subsidence seems to be shown by the annilid jaws of the Conodont bed immediately underneath it; for these animals probably never live in water of any great depth. The more or less broken and fragmentary fish plates and scales may indicate the same thing.

During all this time the deposition of black shales in the southern and western states continued uninterruptedly, these according to H. S. Williams,* representing the Marcellus, Genesee, and Ithaca shales.

CONCLUSION.

If any general conclusion is to be drawn from the foregoing discussions it is that in every locality the development of the faunas at any horizon depend largely upon local conditions, and a fauna which may characterize one part of a group at one locality, may characterize a different portion of the same group at another locality, and that consequently close correlations can not be made, without taking all the local factors into consideration.

While this makes of stratigraphy a vastly more difficult and intricate subject, it also greatly enhances the value and interest which it possesses, when regarded from a purely scientific point of view.

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*Proc. A. A. A. S. vol. 30, p. 186.

ADDENDUM.

A reëxamination of the strata in Avery's creek and in Erie cliff, has shown that the Nautilus bed does not rest directly upon the Strophalosia bed, but that about seven feet of shale intervene. Recent favorable exposures in Avery's creek have allowed the investigation of these beds to some extent, though no complete section could be obtained. The best, for purposes of measurement, though not for collecting fossils, is near the southern end of Erie cliff, where the strata are apparently in place, and where the Strophalosia and Nautilus beds are about seven feet apart.

The following species have been obtained from exposures in Avery's creek, just above the fall. The relation of the beds, which furnished the fossils, to the Nautilus and Strophalosia beds, is only approximately given, as the exposures did not admit of accurate measurements.

(*a*) Shale, one foot above Strophalosia bed.

Crustacea:

1 Phacops rana. c

Lamellibranchiata:

36 Pterinopecten conspectus. r
40 Pterinea flabella. r

Brachiopoda:

91 Stropheodonta perplana. rc
99 Chonetes scitula. r
100 C. lepida. rc
105 Spirifer mucronatus. rc
Crinoid stems. r

Bryozoa:

141 Stictopora incisurata. C

Anthozoa:

152 Streptelasma rectum. r
Coral.

(*b*) Heavy bedded shale between two and three feet above the Strophalosia bed. The following fossils have been collected:

Crustacea:

1 Phacops rana. c
2 Cryphæus Boothi. R
6 Primitiopsis punctulifera. rc

Pteropoda:

15 Styliolina fissurella. rc

Lamellibranchiata:

36 Pterinopecten conspectus. F
37 P. Hermes. R
40 Pterinea flabella. r
50 Cypricardella bellistriata. r
58 Palæoneilo emarginata. r
Palæoneilo, sp.
Orthonota (?) parvula. R

Brachiopoda:

Lingula, sp. R
91 Stropheodonta perplana. r
99 Chonetes scitula. r
100 C. lepida. c
105 Spirifer mucronatus. c
115 S. subumbonus. r
121 Athyris spiriferoides. c
Crinoid stems.

Anthozoa:

151 Pleurodictyum stylopora. r
(Small dwarfed form.)
152 Streptelasma rectum. r
Coral.

Between three and four feet above the Strophalosia bed, occurs a thin layer (*c*) full of *Spirifer subumbonus.*

About a foot below the Nautilus bed (6± ft. above the Strophalosia bed) the following species were found:

(*d*) Laminated shales.

Crustacea :

1 Phacops rana. r
2 Cryphæus Boothi. r

Lamellibranchiata :

42 Actinopteria Boydi. r
50 Cypricardella bellistriata (?). r
68 Tellinopsis subemarginata (?). R

Brachiopoda :

91 Stropheodonta perplana. rc
100 Chonetes lepida. rc
105 Spirifer mucronatus. c
121 Athyris spiriferoides. c
Crinoid stems. c

Table showing the vertical distribution of the invertebrates in the Hamilton Group of Eighteen-Mile Creek and vicinity.

R=very rare. r=rare. rc=fairly common. c=common. C=very common.

	UPPER MARCELLUS SHALES.		HAMILTON OR LOWER SHALES. SPIRIFER MUCRONATUS FAUNA.															
			PLEURODICTYUM BEDS.															
	Transition shales.	Strophalosia bed.	Lower or Nautilus bed.	Middle	Upper.	Calcareous bed.	Shale, 2 ft.	Bryozoa bed.	Shale, 2 ft.	Lower Trilobite bed.	Shale.	Middle Trilobite bed.	Upper Trilobite bed.	Shale and limestone.	Limestone.	Shale, 7 ft.	Modiomorpha subalata bed.	Shale, 4 ft.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CRUSTACEA.																		
1. Phacops rana	r	r		r	rc	rc		R	rc	C	r	C	c	c	r	r	rc	r
2. Cryphæus Boothi	r	R				rc				c	r	c	r			R	r	
2a. C. Boothi var. calliteles												r						
3. Homalonotus Dekayi			r	R			R					R						
4. Proetus macrocephalus																		
5. Proetus sp.						R												
6. Primitiopsis punctulifera	r				rc			r	c		r	r	r	r		r	r	r
CEPHALOPODA.																		
7. Goniatites uniangularis					R													
8. Nautilus magister			c															
9. Orthoceras subulatum		rc																
10. O. nuntium							R					r	rc					
11. O. Telamon																		
12. O. exile		c															?	
PTEROPODA.																		
13. Tentaculites bellulus																		
14. T. gracilistriatus	c												r					
15. Styliolina fissurella	c									rc		r	r				r	
16. Coleolus gracilis																		
17. C. tenuicinctum			r															
GASTEROPODA.																		
18. Platyceras erectum																		
19. P. carinatum												r						
20. P Thetis				r														
21. P. bucculentum																		
22. P. symmetricum				R														
23. P. attenuatum										r								
24. Platyostoma lineatum			r	rc	rc	rc		R	rc	r								
25. Euomphalus laxus	R																	
26. E. rudis																		
27. Pleurotomaria Lucina																		
28. P. Lucina var. perfasciata				R														
29. P. Itys			rc		r													
30. P. capillaria		rc																
31. Loxonema Hamiltoniæ		c																
32. L. delphicola		rc																
33. Bellerophon Leda	R	C	r	R			R											
LAMELLIBRANCHIATA.																		
34. Aviculopecten princeps									r			r		r				
35. A. exacutus																		
36. Pterinopecten conspectus					rc													
37. P. Hermes						r												
38. P. undosus																		
39. P. sp.																		
40. Pterinea flabella																		
41. Actinopteria decussata				r	c	r												
42. A. Boydi				r		r												
43. Liopteria Rafinesquii																		
44. L. sp.																		
45. Plethomytilus oviformis																		
46. Modiomorpha concentrica				r	r	r			r									r
47. M. subalata					r				R	rc		c		r			C	
48. M. alta				R														
49. Goniophora modiomorphoides																		
50. Cypricardella bellistriata		R			rc	r	r										r	
51. Nuculites oblongatus		rc																
52. Nuculites Nyssa		rc																

	HAMILTON OR LOWER SHALES. SPIRIFER MUCRONATUS FAUNA.										MOSCOW SHALES. LOWER SPIRIFER CONSOBRINUS FAUNA.				MIDDLE BARREN 8 FT.	UPPER SPIRIFER TULLIUS FAUNA.		
	Shale, 12 ft.	Athyris spiriferoides bed.	Shale, 2-3 ft.	Shale, 5 ft. below Encrinal.	Pteropod bed, 4 ft. below Encrinal.	Shale, 2-3 ft. below Encrinal.	Stropheodonta demissa bed	Stictopora bed.	Encrinal limestone.	Shale, 1½ ft.	Coral layer, 3 in.	Shale, 1 ft.	Shale, 2 ft.	Orbiculoidea media bed.	Shale, 1-2 ft.	Shale, 2 ft.	Transition shales. Schizobolus fauna. 1 ft.
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
CRUSTACEA.																	
1. Phacops rana	c			r		c	c	c	c	rc		c	rc			r	
2. Cryphæus Boothi	c							r	r	r			r				
2a. C. Boothi var. calliteles									?								
3. Homalonotus Dekayi																	
4. Proetus macrocephalus									R								
5. Proetus sp.																	
6. Primitiopsis punctulifera	rc	r	rc	rc	c	rc	r										
CEPHALOPODA.																	
7. Goniatites uniangularis																	
8. Nautilus magister																	
9. Orthoceras subulatum						R			R							R	
10. O. nuntium																	
11. O. Telamon									r								
12. O. exile	?																
PTEROPODA.																	
13. Tentaculites bellulus	r	r	r				r	r								?	
14. T. gracilistriatus					C		r									C	r
15. Styliolina fissurella	c		rc	rc	C												rc
16. Coleolus gracilis							R										
17. C. tenuicinctum																	
GASTEROPODA.																	
18. Platyceras erectum							r										
19. P. carinatum							rc		rc								
20. P Thetis							r										
21. P. bucculentum									R								
22. P. symmetricum																	
23. P. attenuatum							r	rc	rc								
24. Platyostoma lineatum							c	c	rc				r				
25. Euomphalus laxus									R								
26. E. rudis									R								
27. Pleurotomaria Lucina									R								
28. P. Lucina var. perfasciata																	
29. P. Itys																	
30. P. capillaria																	
31. Loxonema Hamiltoniæ																	
32. L. delphicola																	
33. Bellerophon Leda																	
LAMELLIBRANCHIATA.																	
34. Aviculopecten princeps	r						rc		r								
35. A. exacutus	r		r				rc	r									
36. Pterinopecten conspectus	r		r			r	rc						r				
37. P. Hermes																	
38. P. undosus							r										
39. P. sp.							R										
40. Pterinea flabella	r					r	c	r									
41. Actinopteria decussata							r	rc	rc								
42. A. Boydi																	
43. Liopteria Rafinesquii							R										
44. L. sp.							R										
45. Plethomytilus oviformis									c								
46. Modiomorpha concentrica									c								
47. M. subalata	r					R											
48. M. alta																	
49. Goniophora modiomorphoides									c								
50. Cypricardella bellistriata	r								R								
51. Nuculites oblongatus					R												
52. Nuculites Nyssa																	

Table showing the vertical distribution of the invertebrates in the Hamilton Group of Eighteen-Mile Creek and vicinity – Continued.

R=very rare. r=rare. rc=fairly common. c=common. C=very common.

	UPPER MARCELLUS SHALES.		HAMILTON OR LOWER SHALES.																									MOSCOW SHALES.							
			SPIRIFER MUCRONATUS FAUNA.																									LOWER SPIRIFER CONSOBRINUS FAUNA.				MIDDLE BARREN 8 FT.	UPPER SPIRIFER TULLIUS FAUNA.		
			PLEURODICTYUM BEDS																																
	Transition shales.	Stropholosia bed.	Lower or Nautilus bed.	Middle.	Upper.	Calcareous bed.	Shale, 2 ft.	Bryozoa bed.	Shale, 2 ft.	Lower Trilobite bed	Shale.	Middle Trilobite bed.	Upper Trilobite bed.	Shale and limestone.	Limestone.	Shale, 7 ft.	Modiomorpha subalata bed.	Shale, 4 ft.	Shale, 12 ft.	Athyris spiriferoides bed.	Shale, 2-3 ft.	Shale, 5 ft. below Encrinal.	Pteropod bed 4 ft. below Encrinal.	Shale, 2-3 ft. below Encrinal.	Stropheodonta demissa bed.	Stictopora bed.	Encrinal limestone.	Shale, 1½ ft.	Coral layer, 3 in.	Shale, 1 ft.	Shale, 2 ft.	Orbiculoidea media bed.	Shale, 1-2 ft.	Shale, 2 ft.	Transition shales. Schizobolus fauna. 1 ft.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
LAMELLIBRANCHIATA — (*Continued*).																																			
53. N. triqueter	r																																		
54. Palæoneilo constricta							R												R					R	R										
55. P. tenuistriata		R							R			r					r	rc	r	r				r				R		c					
56. P. fecunda																			rc	rc	r			rc	rc			r		rc					
57. P. muta		R				R						R							r					r	r	r		rc							
58. P. emarginata																	r	rc	rc	r	rc			r	rc										
59. Macrodon Hamiltoniæ																			R																
60. Grammysia arcuata?																			R																
61. G. sp																			R																
62. Sphenotus truncatus																									R										
63. Conocardium sp																											r								
64. Lunulicardium fragile	c																		R																
65. Pholadella radiata																	r		r																
66. Cypricardinia indenta						r			rc															R	C	c		?							
67. Modiella pygmæa		r															R																		
68. Tellinopsis subemarginata		R																																	
69. Glyptocardia speciosa		R																																	
BRACHIOPODA.																																			
70. Lingula Leana																			rc		r														
71. Lingula Delia																	r		r																
72. L. spatulata																			rc						r										
73. L. sp																									R										
74. Orbiculoidea media																	R		R													c			r
75. O. Doria																																r			
76. O. Lodensis			R																						R										
77. Schizobolus truncatus																																r	R	r	C
78. Craniella Hamiltoniæ									r										r						r	r				r					
79. Pholidops Hamiltoniæ											r	r						rc	c	r	rc		R		rc	r		c		r					
80. P. linguloides																									r		r								
81. P. oblata																											r								
82. Rhipidomella Vanuxemi						rc			rc			r					r	r	rc	r	r	r		r	c	C	C				r				
83. R. Leucosia									rc																		r								
84. R. Penelope									r																r	r	c								
85. R. idoneus																											r				R				
86. R. cyclas									R																										
87. Orthothetes arctostriata	r			rc	rc	r						r						rc	c		rc	rc	R	rc	c	r					r		r	r	R
88. O. perversa				r															r						r	r									
89. Stropheodonta demissa																								R	C	R	R								
90. S. concava						r			R																C		?								
91. S. perplana			R	rc	rc	rc	r					r						rc	c	r	r	r		rc	c	rc	rc	c		rc					
92. S. inequistriata						rc		rc	rc	c		r													C	rc	r				rc				
93. S. nacrea						r			R	c		r					r										rc								
94. S. junia																									r										
95. S. plicata																									r										
96. Chonetes mucronata	r			r																							r			c	r			r	
97. C. deflecta					r				r																		r	rc		C	r				
98. C. setigera	r			R	r														r					r											
99. C. scitula	r		rc	rc	rc		r		c	r	R					rc		rc	C	r				rc	c	r	r	r						r	
100. C. lepida	rc		rc	rc		rc	r		R		r	r	c	c		rc	rc	rc	C	r	rc	rc	R	rc	rc	r		r		r				r	r
101. C. coronata					r	r																		r	rc	r	rc								
102. Productella navicella																											r								
103. P. spinulicosta	r				r			R	rc		r	r					r	rc	rc		r				rc	c	r						rc		
104. Strophalosia truncata	r	C	R																																
105. Spirifer mucronatus	rc	c	rc	r	rc	rc	r	rc	c	rc	r	r	rc	c	c	rc	r	c	C		r	rc		c	C	C	R			R		R		R	
106. S. Tullius																																	r	c	
107. S. sculptilis																											rc								
108. S. consobrinus																												rc		c					
109. S. granulosus		R	r	C	c	c	R		R															r	c		C								
110. S. audaculus					rc	rc			rc		r													rc	c	c	rc		rc	rc					
111. S. angustus																									r										

Table showing the vertical distribution of the invertebrates in the Hamilton Group of Eighteen-Mile Creek and vicinity—Concluded.

R=very rare. r=rare. rc=fairly common. c=common. C=very common.

	Upper Marcellus Shales.		Hamilton or Lower Shales.																									Moscow Shales.							
			Spirifer mucronatus Fauna.																									Lower Spirifer consobrinus Fauna.				Middle Barren 8 Ft.	Upper Spirifer Tullius Fauna.		
			Pleurodictyum beds.																																
	Transition shales.	Strophalosia bed.	Lower or Nautilus bed.	Middle.	Upper.	Calcareous bed.	Shale, 2 ft.	Bryozoa bed.	Shale, 2 ft.	Lower Trilobite bed.	Shale.	Middle Trilobite bed.	Upper Trilobite bed.	Shale and limestone.	Limestone.	Shale, 7 ft.	Modiomorpha subalata bed.	Shale, 4 ft.	Shale, 12 ft.	Athyris spiriferoides bed.	Shale, 2-3 ft.	Shale, 5 ft. below Encrinal.	Pteropod bed, 4 ft. below Encrinal.	Shale, 2-3 ft. below Encrinal.	Stropheodonta demissa bed.	Stictopora bed.	Encrinal limestone.	Shale, 1½ ft.	Coral layer, 3 in.	Shale, 1 ft.	Shale, 2 ft.	Orbiculoidea media bed.	Shale, 1-2 ft.	Shale, 2 ft.	Transition shales, Schizobolus fauna, 1 ft.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Brachiopoda—(*Continued*).																																			
112. S. macronotus									r															r	rc	c	c								
113. S. asper																									rc										
114. S. fimbriatus					R	R			rc																C	rc	rc								
115. S. subumbonus																								r										r	r
116. Ambocœlia umbonata	rc								rc	r	r	r	r				r		C	r	r				r	r	r	C		c			R	R	R
116a. A. umbonata var. nana		r	C																																
117. A. præumbona																																	c	C	C
118. A. spinosa																		rc	rc		r													r	
119. Cyrtina Hamiltonensis					r	r			r										R			R			c	c				R					
119a. C. Hamiltonensis var. recta					r																														
120. Nucleospira concinna			r			r			rc											r				r	c	C	R				r				
121. Athyris spiriferoides			R	rc	rc	rc		c	c		C						rc		c	C	r			rc	r	r	rc	rc		r	r			r	R
122. Meristella Haskinsi																											r								
123. M. rostrata																											R								
124. Atrypa reticularis																					r			rc	c	r			c		c				
125. A. aspera																													C		R				
126. Vitulina pustulosa																											c								
127. Camarotœchia Horsfordi			?																							r	r			r					
128. C. Sappho				r	rc	r						R							c					r	r		rc								
129. C. Dotis		?	C																								r								
130. C. sp.																											R								
131. Liorhynchus multicostus																r	c	c	C			r								r				r	C
132. L. limitaris	rc																																		
133. L. dubius																			r																
134. Centronella impressa																											c								
135. Cryptonella planirostra					?			R																	r		c								
136. C. rectirostra					c	c																													
137. Dielasma Romingeri				rc	R	rc				r																									
138. Tropidoleptus carinatus	r			rc	r	rc			rc										r				R				C								
Crinoidea.																																			
139. Taxocrinus sp																															R				
140. Ancyrocrinus bulbosus																									r						r				
Bryozoa.																																			
141. Stictopora incisurata					rc			c												r					c	C	r								
142. S. sinuosa								R																											
143. Tæniopora exigua																									R	r									
144. Botryllopora socialis							r																												
145. Reptaria stolonifera																									R										
146. Loculipora perforata																									c										
147. Fenestella emaciata																									c										
148. F. sp.								c											rc						c	c									
Anthozoa.																																			
149. Favosites argus																									R										
150. F. Hamiltoniæ																											C								
151. Pleurodictyum stylopora			rc	C	c																														
152. Streptelasma rectum			r			rc			c	rc	c							r	r					r	c	r		C		rc	c				
153. S. ungula																															r				
154. Zaphrentis simplex																											R		rc						
155. Heliophyllum Halli																									R		r		c						
156. H. confluens																											r								
157. Cystiphyllum americanum																													rc						
158. C. conifollis																									r				C		c				
159. Amplexus Hamiltoniæ																															rc				
160. A. (?) intermittens																															r				
161. Monotrypa fruticosa				r															r						r						rc				
162 Aulopora serpens																				r					r										
163. Craspedophyllum subcæspitosum																											r								

A

MEMOIR

ON THE

PALAEOZOIC RETICULATE SPONGES

CONSTITUTING THE FAMILY

DICTYOSPONGIDÆ.

BY

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IN COLLABORATION WITH

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PART II

CONTINUED FROM THE FIFTEENTH ANNUAL REPORT OF THE STATE GEOLOGIST)

SPECIES OF THE CARBONIFEROUS.

SPECIES OF THE WAVERLY GROUP.

TYLODICTYA, gen. nov.

This generic form is as yet but imperfectly understood. Some recently discovered sponges from Warren, Pennsylvania, present the appearance of erect, reticulated cups, smooth or somewhat irregularly undulated for a considerable part of their length, but abruptly breaking out into one or possibly more whorls of quite unsymmetrical and irregular simple or compound nodes. Apparently there are eight nodes in each whorl, but this is not certain. The nodes are pendulous when large, and in their subdivision have followed no rule or order. The aspect of the cylindrical portions of the sponge is similar to that of the forms of CALATHOSPONGIA with which it is associated, being fine-meshed and free from prismatic faces.

The fragments to which our knowledge of this genus is now restricted, though highly imperfect, are still sufficient to distinguish it from any other.

Type, *Tylodictya Warrenensis*, sp. nov.

TYLODICTYA WARRENENSIS, sp. nov.

Erect, subcylindrical cups, apparently contracting slightly above the base; surface smooth for a considerable distance, then gently expanding and developing a horizontal row of nodes. In the smaller of the fragments which have been observed, these nodes are low, simple, somewhat elongate vertically and divided by narrow furrows which reach to the general surface of the sponge, displaying no tendency to subdivision or irregularity of arrangement; in the larger specimen less of the inferior surface of the cup is retained, but the nodes are very strongly developed, are vertically elongate, and were apparently somewhat fan-shaped, are pendent toward their rounded extremities and separated by grooves of different depth, so that each pair of nodes seems to be elevated on a stout base, as with the nodes in certain species of HYDNOCERAS. Upon one side of this specimen the nodes are much less regular than on the other, one pair having appeared below the others. This pair is divided very unequally by a vertical groove and again horizontally, so that the effect produced is somewhat like that observed among the nodes of BOTRYODICTYA. To what extent

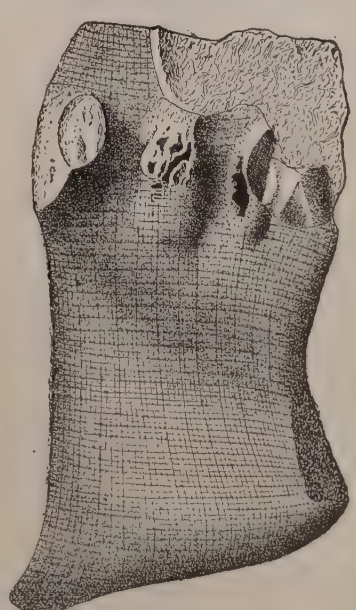

FIGURE 18. *Tylodictya Warrenensis*, Warren, Pennsylvania. A young individual bearing nodes only toward the upper part.

this condition of the nodes is normal and in how far the sponge is affiliated with the last named genus can not at present be determined.

The *reticulum* is very fine-meshed, bearing no conspicuous major divisions, and resembles that of CALATHOSPONGIA.

Of the two specimens referable to this species, one has a length of 75 mm., the lower portion of the cup to the base of the nodes measuring 50 mm. At

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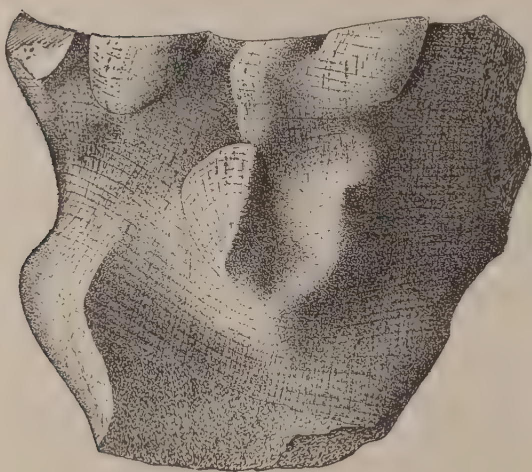

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FIGURES 19, 20. *Tylodictya Warrenensis*, Waverly sandstone, Warren, Pennsylvania.

Figure 19 gives a side view of the type specimen in which the strong, irregular nodes are much foreshortened. The prominence of these nodes is brought out in figure 20, in which the specimen is viewed from above.

its base this specimen has a width of 45 mm., and its diameter at mid-length is 35 mm. The other fragment is 65 mm. in length and is broken across the expanded nodiferous portion, measuring in diameter to the extremities of the nodes, 90 mm.

Locality. In the Waverly sandstone, Warren, Pennsylvania. (Collection of Prof. C. E. BEECHER.)

TYLODICTYA (?) TENUIS, Hall (sp.).

PLATE LIII, FIGS. 4, 5.

1882. *Dictyophyton tenue*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 18, fig. 5.

1884. *Dictyophyton tenue*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 474, pl. 18 (19), fig. 5.

The only known specimen of this species is a small fragment of a cup bearing two large, compound nodes separated by a deep longitudinal groove,

and each divided across the top by a low furrow. The nodes are vertically elongated, not constricted at the base, and the lobes are low and obtuse.

The *reticulum* is composed of very fine spicular bands among which scarcely any difference in size is apparent. There is no evidence of a prismatic division of the surface. So few specific characters are retained by this single fragment that it is referred with considerable hesitation to the genus TYLODICTYA; yet its nodose surface suggests such relationship and its occurrence in the same fauna with *T. Warrenensis* enforces this suggestion.

Locality. In the Waverly sandstone, at Warren, Pennsylvania.

CLATHROSPONGIA, Hall.

(For description see page 861, part 1.)

CLATHROSPONGIA ABACUS, Hall.

PLATE XLIX, FIGS. 5–8.

1882. *Clathrospongia abacus*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 18, figs. 2–4.

1884. *Dictyophyton* (*Clathrospongia*) *abacus*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 474, pl. 18 (19), figs. 2–4.

SPONGE of moderate size, regularly turbinate or obconical; actual base not preserved, but judging from the slope of the sides, acute. Expansion rather rapid. Aperture unknown.

Surface bearing coarse primary spicular ridges, which enclose quadrules measuring on the average 10 mm. in width and 9 mm. in length. These are subdivided into four squares by the secondary spicular bands; the finer divisions of the reticulum may also be preserved. The primary bands are extended into free horizontal and vertical expansions measuring about 8 mm. in width and the deep fenestrations thus made are divided into smaller areoles by the crossing of the subordinate reticulating bands in each; this inference is, at least, to be made from the appearance of finer reticulating lines on the surface of the primary expansions.

Dimensions. Length of the original specimen, 100 mm.; greatest diameter of the cup (at upper extremity), 50 mm.; median diameter, 38 mm. without, and 54 mm. with the lamellar expansions.

Locality In the sandstones of the Waverly group, associated with *Ectenodictya implexa*, and an undetermined *Spirifer* or *Syringothyris;* Warren, Pennsylvania.

CLATHROSPONGIA CAPRODONTA, sp. nov.

PLATE L, FIGS. 8, 9.

SPONGE slender, elongate obconical, gradually enlarging from an acute base to the aperture, the rate of expansion being the most rapid over the earliest one-third of the length. Surface faintly subprismatic, with low nodes at the intersection of the primary spicular bands.

Upon the single specimen observed, which is an internal cast, the reticulum shows twelve longitudinal spicular ridges which, with the intersecting horizontal ridges of about the same size, form large primary quadrules. Over the body of the cup these measure about 13 mm. in width and 19 mm. in length, making a comparatively large quadrule which was evidently very sharply defined over the entire cup, except at the base and about the aperture. The angles of these quadrules bear pronounced nodes, not so highly developed as in HYDNOCERAS, but indicating a tufted projection of the spicules, undoubtedly accompanied by a strong lamellar spicular band along the primary vertical and horizontal ridges. These ridges and nodes are somewhat obscured by the secondary reticulation, the entire surface being covered with meshes measuring about 2 mm. on a side, the intermediate reticulation being virtually lost.

The cup has an entire length of 185 mm. and an apertural diameter of 63 mm. Its diameter at 50 mm. from the apex, is 38 mm., and at 125 mm. from the base, it is 57 mm.

Locality. In the sandstone of the Waverly group, at Portsmouth, Ohio. (Collection of the School of Mines, Columbia University, New York.)

THYSANODICTYA, gen. nov.

(For description see page 865, part 1.)

THYSANODICTYA EXPANSA, Hall (sp.).

PLATE LIII, FIG. 3.

1882. *Phragmodictya expansa*, Hall Notes on the Family Dictyospongidæ; Expl. pl. 19, fig. 10.

1884. *Ectenodictya expansa*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 475, pl. (19) 20, fig. 10.

The original specimen of *Ectenodictya expansa* is a portion of a very large basal disc or diaphragm, representing a species of those forms occurring abundantly in the Chemung sandstones for which we have erected the genus THYSANODICTYA. The species is somewhat irregularly nodose over the surface

and quite strongly so at the margins, the elevations there being elongated and extended for some distance over the basal surface; presenting an aspect similar to this part of the cup in *Th. Edwin-Halli* and *Th. rudis*, of the Chemung group.

The *reticulum* is irregular, as in all of these basal disks which have been subjected to compression, but at certain spots a strong reticulation is retained, composed of major quadrules measuring about 6 mm. on a side, subdivided by two or three series of subordinate bands. The primary ridges are elevated and indicate a strong and coarse net-work over the lateral walls of the cup.

The diameter of this disc is 150 mm., a size which is not attained by specimens of any other species of the genus.

Locality. In the sandstone of the Waverly group, Warren, Pennsylvania.

CALATHOSPONGIA, gen. nov.

1863. *Dictyophyton*, Hall. Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 88.

1882. *Phragmodictya ?*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 17, fig. 9.

1884. *Dictyophyton ?*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 474.

Stout, subcylindrical cups, with truncated bases, without basal cone or diaphragm as far as known, but probably attached by the basal margins; contracted medially and more or less expanded at the aperture. Surface without nodes or other ornament.

Type, *Dictyophyton Redfieldi*, Hall.

CALATHOSPONGIA REDFIELDI, Hall (sp.).

PLATE XLVIII, FIGS. 1, 2; PLATE XLIX, FIGS. 1–4.

1863. *Dictyophyton Redfieldi*, Hall. Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 88, pl. v, fig. 1; pl. v a, fig. 1.

1882. *Phragmodictya ? Redfieldi*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 17, fig. 9.

1884. *Dictyophyton ? Redfieldi*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 474, pl. (17) 18, fig. 9.

1889. *Dictyophytum Redfieldi*, Lesley. Dictionary of Fossils, p. 200.

SPONGE large, probably subcircular in cross-section; base broad, expanded at the margin; the basal expansion continues for about one-third the length of

the cup, passing upward into a long, shallow constriction; the apertural part of the cup is again gradually expanded, the greatest diameter being at the aperture, which is unconstricted. The normal form of the sponge as thus described, is best represented by the example shown upon Plate xlix, (figs. 2 and 3) which is essentially entire. The skeleton of this species was evidently very delicate and fragile, as larger specimens are all more or less broken and distorted. Surface quite smooth.

Reticulum composed of fine and minute quadrules. Very faint longitudinal ridges are visible in places, especially upon one side of the largest observed example, but these can be discerned only over the apertural part of the cup. The more noticeable spicular bands are the horizontal ones which succeed each other at pretty regular intervals of from 3–4 mm. The vertical bands corresponding with these are rarely well preserved, so that the usual aspect of the surface is a succession of narrow horizontal bands. The quadrules formed by the horizontal bands and their corresponding vertical bands are subdivided by four subordinate series of spicules, so that the ultimate division of the surface, which is usually sharply retained, is very minute. Upon certain portions of any given specimen, the coarser reticulation may be wholly lost, leaving traces of only the finer division of the reticulum. The apertural margin is regular and entire.

Dimensions. A small, but entire and slightly compressed example has a length of 70 mm.; it measures 32 mm. in diameter at the base; 30 mm. just above the base, and 33 mm. at a distance of 10 mm. above the base; at the middle of the cup its diameter is 25 mm., and at the aperture, 51 mm. A large example has been somewhat shortened by vertical compression which has produced an abnormal swelling about the middle of the cup. Its length is 183 mm.; its basal diameter about 96 mm.; at a point slightly above the middle, 72 mm.; and at the aperture, 135 mm. The original specimen has a length of 200 mm.; a basal width of 86 mm.; a median width of 38 mm., the upper part of the cup, which is somewhat distorted, being 105 mm. in diameter.

Localities. The specimen upon which the original description of the species was based was collected near Harrisville, Medina county, Ohio, in a yellowish sandstone of the Waverly group, by the late W. C. REDFIELD. It has also been found in the Cuyahoga shale of the Waverly group, at Akron, and at Richfield, Ohio, and also in the Waverly sandstone on Nelson's farm near Pleasantville, Venango county, Pennsylvania.

CALATHOSPONGIA CARCERALIS, sp. nov.

PLATE LI, FIGS. 2–4; PLATE LII, FIGS. 2, 3; PLATE LX, FIGS. 1, 2.

1863. *Dictyophyton Newberryi*, Hall. Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., pl. iv, fig. 3.

Among the specimens utilized for the original illustration of the species *Dictyophyton Newberryi*, was one large subcylindrical cup which was doubtfully regarded as representing the pedicel of that species. A re-examination of this specimen, supplemented by other material, some of which has been collected since the date of that description, shows very clearly that such specimens represent a quite distinct form of sponge.

CUP elongate, rather stout, probably circular in cross-section, though all the specimens are more or less flattened. Base broad, terminating abruptly; from the base upward the body contracts slowly and then very gradually expands to the aperture. The form is thus somewhat like that in certain species of THYSANODICTYA (e. g. *Th. pœcilus*) but the truncated base affords no evidence of a diaphragm or any other method of closure.

The *reticulum* is characterized by strong vertical and horizontal primary ridges, the former being the more conspicuous and in some instances so highly developed as to give a subprismatic appearance to the cup. In the specimens from the Waverly sandstones these vertical ridges are twelve in number and their intersection with the principal horizontal ridges forms quadrules measuring about 8 mm. in width and 12 mm. in height; the development of the horizontal spicular ridges is, however, quite variable. The subordinate reticulation is sharply developed. The apertural margin is regular and the primary reticulation extends to it without material loss of definition.

Dimensions. The original example which is essentially entire, has a length of 145 mm.; a width at the base of 33 mm.; at 40 mm. above the base the diameter increases to 46 mm.; decreases above to 43 mm.; and expands to the aperture which is 65 mm. in width. This specimen is from the Waverly group. An entire specimen from the Keokuk group is 130 mm. in length; 48 mm. in diameter at the base; 75 mm. at the aperture, and 40 mm. where narrowest.

Localities. In the shales and sandstones of the Waverly group at Richfield Ohio; also in the calcareous shales of the Keokuk group at Indian Creek, Indiana. (The latter from the collection of A. S. TIFFANY.)

CALATHOSPONGIA CARLLI, sp. nov.

PLATE LII, FIGS. 4–7.

Among some specimens of Dictyosponges from the Waverly group of northern Venango county, Pennsylvania, kindly loaned for study by Mr. JOHN F. CARLL, formerly of the Second Geological Survey of that state, is one rather large specimen of the upper portion of the cup which in the aspect of the surface, bears no little similarity to *C. Redfieldi* but it has a proportionally much broader aperture than is possessed by that species. The specimen has been somewhat compressed obliquely, but apparently without serious distortion to the best exposed surface. The body of the cup is moderately narrow, measuring 55 mm.; the width of the aperture is 145 mm., but this is perhaps somewhat below its original proportions as the apertural portion of the cup has been slightly enfolded on one side.

The character of the *reticulum* is essentially the same as that of *C. Redfieldi*, the surface being crossed transversely by numerous strong spicular bands, while the vertical bands are very fine and all trace of conspicuous vertical ridges is wanted.

Localities. In the sandstones of the Waverly group. "Found loose on the flats of Oil Creek, near the mouth of Pine Creek. The stream here cuts down about 15 feet below the Berea grit" (Mr. CARLL's letter); near Pleasantville, Venango county, Pennsylvania. The species also occurs in the same rocks at Warren, Pennsylvania, and some of the specimens from there, like that shown in figure 21, page 352, indicate the probable identity of *C. Carlli* with the fragmentary remains described as *Ectenodictya implexa.*

CALATHOSPONGIA TIFFANYI, sp. nov.

PLATE LI, FIGS. 5, 6.

SPONGE subcylindrical toward the base, expanding with moderate rapidity to the aperture, producing an elongate, subconical vase-shape. Surface with obscure traces of prismatic faces which widen upward. Where best preserved these faces are seen to be marked by moderately strong spicular ridges crossed by less prominent bands, the two making quadrules measuring approximately 12x10 mm. where the faces are least expanded, but increasing in width, without increase of length, toward the aperture. The intersections of these primary bands are obscurely nodose. The subdivision of the quadrules to the fifth degree is very clearly seen on the internal cast. The surface is otherwise devoid of ornamentation.

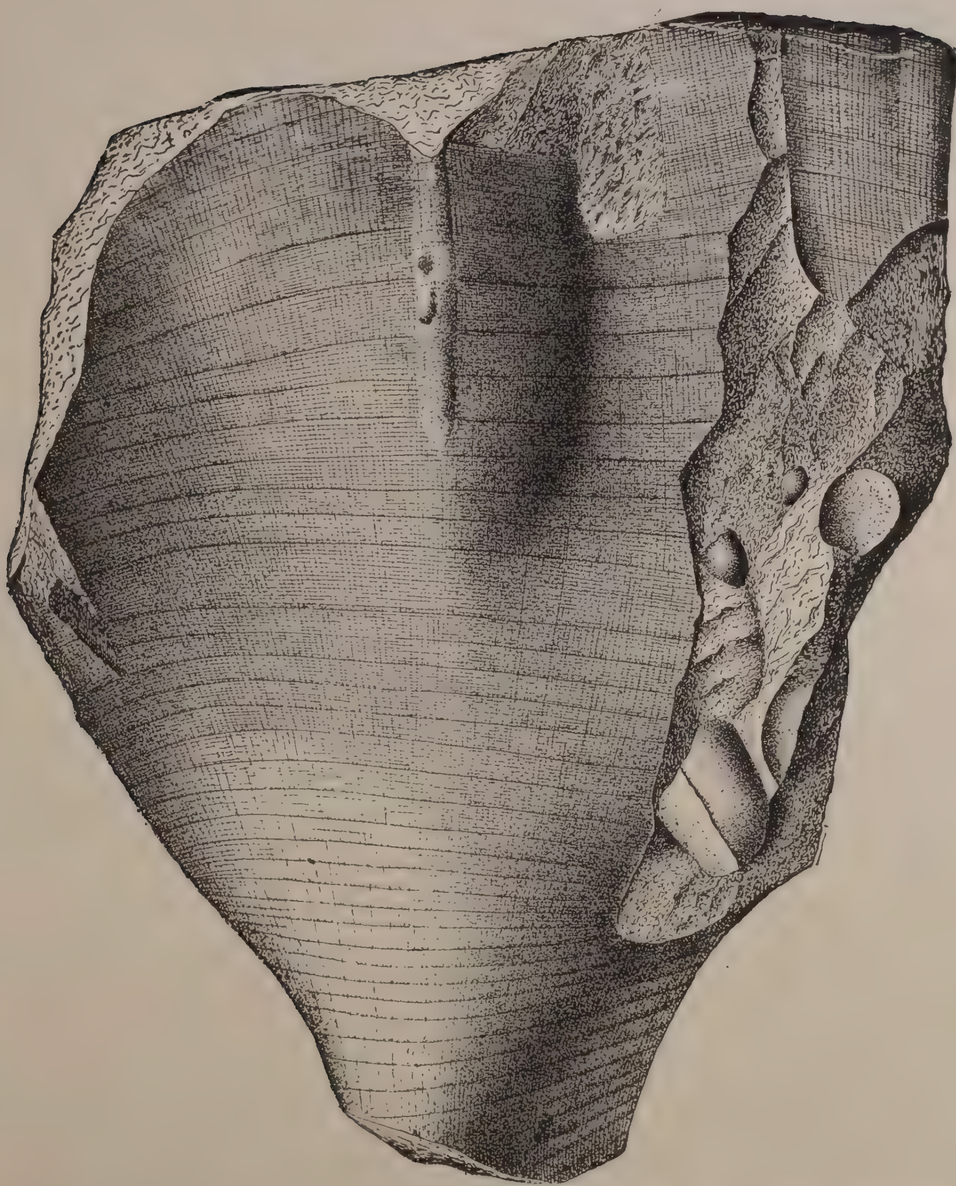

FIGURE 21. Portion of a large specimen of *Calathospongia Carlli*, from the Waverly sandstone at Warren, Pennsylvania.

The type specimen, which is imperfect toward the base, has somewhat the aspect of *C. carceralis* and evinces a probable agreement in form with the other species of the genus CALATHOSPONGIA. Its condition of preservation is not such as to show with certainty specific differences from *C. carceralis* except in its stouter form and more rapid apertural expansion

Dimensions. Length (incomplete) 100 mm.; apertural diameter (slightly flattened) 84 mm.; diameter at lower extremity, 39 mm.

Locality. Waverly group, Ohio. (Loaned by A. S. TIFFANY.)

CALATHOSPONGIA ? SACCULUS, Hall (sp.).

PLATE L, FIG. 7.

1863. *Dictyophyton Redfieldi*, Hall. Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., pl. iv., fig. 6.

1884. *Dictyophyton sacculum*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 473.

The specimen upon which this species (?) was founded is a small, short, apparently subcylindrical cup, with a smooth surface and very fine reticulum. One extremity is rather irregular and apparently incomplete, while the other seems to be closed or enfolded. There is very slight, if any, increase in diameter from one end to the other. It seems probable that the specimen is incomplete and affords no precise conception of its original form. The reticulation is somewhat similar to that of *Calathospongia Redfieldi*, but lacks the strong horizontal bands of that species. Its recognition as a species and its reference to this genus are only provisional.

The length of the specimen is 33 mm.; its width about 18 mm.

Locality. In the shaly sandstone of the Waverly group at Richfield, Ohio.

THAMNODICTYA, Hall.

1863. *Dictyophyton*, Hall. Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 87.

1882. *Phragmodictya*, Hall. Note on the Family Dictyospongidæ; Expl. pl. 17, figs. 10, 11.

1884. *Thamnodictya*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., pp. 466, 477.

Dictyosponges with a narrow, subcylindrical, tubular stem below, abruptly widening above into a broad funnel-shaped circular cup. Surface with prominent spicular ridges, but without nodes or well defined prism-faces.

Type, *Thamnodictya Newberryi*, Hall.

In the observations made upon the genus HYDNOCERAS, reasons have been given for discontinuing the generic term DICTYOPHYTON. It is not necessary to recount these further than to recall that the term was introduced, not primarily to replace CONRAD's name HYDNOCERAS, but as a designation for other, and anodose species, the first among the specified types being *Dictyophyton Newberryi*, the form subsequently adopted as the type of THAMNODICTYA. DICTYOPHYTON has proved to be a misleading term among the sponges, and its place is better filled by the various generic terms which the requirements of our present knowledge have originated.

THAMNODICTYA NEWBERRYI, Hall.

PLATE L, FIGS. 1–6; PLATE LII, FIG. 1.

1863. *Dictyophyton Newberryi*, Hall. Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 87, pl. iv, figs. 1, 2, 4, (not fig. 3).

1882. *Phragmodictya Newberryi*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 17, figs. 10, 11.

1884. *Thamnodictya Newberryi*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat., Hist., p. 477 (partim) pl. (17) 18, figs. 10, 11.

SPONGE of moderate size, attenuate and subcylindrical toward the base, rapidly expanding above, forming a broad vase supported upon a long pedicel. Cross-section at any point of the vase circular; the pedicel however appears to have been obscurely prismatic.

Reticulum composed of strong rectangularly intersecting bands, the primary series being broad and forming trapezoidal quadrules, averaging, over the main portion of the vase, about 6 mm. in diameter and 9 mm. in height. The vertical strands diverge very rapidly outward with the growth of the cup, losing their conspicuous size toward the aperture. The subordinate net-work is sharp and fine, especially in the apertural region where the prevalence of the finer strands obliterates the coarser meshes. The pedicel, which is not well preserved in any of the specimens studied, appears to have borne coarse vertical ridges toward its upper part.

Dimensions. The original example of this species is the most complete in the collections examined. Its length from the lower end of the pedicel, which appears to be nearly complete, to the aperture, is 115 mm.; the median width of the pedicel, 7 mm.; the diameter of the aperture, 90 mm. Portions of

other specimens of about the same size have been observed, but the majority of these are of small size.

Under this specific name we have included only the slender forms possessing the expanded aperture. In previous descriptions some much larger subcylindrical bodies have been regarded as pedicels of the same species, but their size and general aspect, supplemented by some additional structural details, indicate that these latter forms are quite distinct from typical examples of THAMNODICTYA.

Localities. In the beds of the Waverly group. The original example, that shown on Plate 1, fig. 1, is from a shaly limestone filled with *Fenestella* and *Productus*, at Richfield, Ohio. Other specimens are from sandy shales and limestones at Cuyahoga Falls, Ohio.

THAMNODICTYA ORTONI, sp. nov.

PLATE LIII, FIGS. 1, 2.

This species is represented by an internal cast, in a compact ferruginous sandstone, of the upper or vase-shaped portion of a THAMNODICTYA. It is a large, somewhat compressed individual preserving a considerable portion of the aperture. At its lower point, which represents the opening of the pedicel, the surface shows several somewhat unequal clusters of the longitudinal spicules which have been changed to limonite. The impression of the reticulum is fine and rather irregular. There are no predominant vertical and horizontal spicular ridges as in *Thamnodictya Newberryi*, but the entire surface is covered by small quadrules about 2 mm. square and these are again divided by minute subordinate bands. The course of the vertical bands is not radial from the base, but they appear to have made a broad simple curve in extending toward the aperture, a feature which may be exaggerated by the compression of the specimen. Along the apertural margin the net-work is much finer than elsewhere.

The specimen measures from base to aperture, on one side, 80 mm. and on the other, 97 mm.. Its greatest diameter is from one edge of the folded apertural margin to the other; each of these lateral extremities is somewhat broken but the full measurement was about 150 mm. The lower sides of the cup slope at an angle of about 60 degrees.

Locality. In the Cuyahoga shale of the Waverly group, Moot's run, Licking county, Ohio. (Named for Dr. EDWARD ORTON, of Columbus, Ohio.)

CLEODICTYA, Hall.

1884. *Cleodictya*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., pp. 467, 479.

Vase-shaped Dictyosponges, broadly expanded near the base into a single horizontal row of strong low nodes, thence gradually contracted and again widening to a broad aperture. Surface without evidence of prismatic faces or projecting spicular lamellae.

Type, *Cleodictya gloriosa*, Hall. Keokuk group.

CLEODICTYA CLAYPOLEI, sp. nov.

PLATE LI, FIG. 1.

SPONGE comparatively small, subturbinate, expanding rather rapidly from the basal extremity into a single horizontal row of nodes which begin a short distance above the base and extend through fully one-third the length of the cup. These nodes, though some are lost on one side of the sponge, appear to have been eight in number, and were low and elongate, their length measuring twice their width; they are separated by narrow furrows which do not extend down to the unswollen surface of the sponge. Above these nodes the surface is abruptly constricted and thence widens very gradually upward, the apertural margin not being retained. The proportions of this species are different from those of *C. gloriosa*, the form being more slender, the expansion more gradual and the basal nodes much more elongate.

The *reticulum* is very fine and the primary divisions somewhat obscured. A series of transverse bands 3–4 mm. apart, crosses the cup, without vertical bands of corresponding strength. This gives to the reticulum the aspect of that in *Calathospongia Redfieldi* and *C. Carlli*. Minor subdivisions to the fifth series are discernible.

Dimensions. The specimen described is somewhat imperfect at both extremities; it does not, however, seem probable that much has been lost from either. The entire length of the portion retained is 102 mm. Its basal extremity has a diameter of 25 mm.; across the row of nodes the diameter is 70 mm.; just above these nodes it is 45 mm. and at the upper extremity, 50 mm.

Locality. From the sandstones of the Waverly group at Akron, Ohio. (Received from Prof. E. W CLAYPOLE.)

(?) ECTENODICTYA, Hall.

1884. *Ectenodictya*, Hall (partim). Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 466.

The name ECTENODICTYA was introduced for certain forms of apparently more or less irregular growth, which seemed to have expanding or unenclosed fronds. Both in the upper Devonian and the lower Carboniferous faunas sponges of such aspect have been found, with a surface usually free of nodes or other ornamental characters. The absence of a well defined form in these species was the principal reason for placing them together under a single generic term, although the division could, by the very nature of its composition, have little more than a temporary value. In 1884, two species, *E. implexa* and *E. expansa* were described from the Waverly sandstone, *E. Burlingtonensis* from the Burlington group and *E. eccentrica* from the Keokuk group. Fossils of like character are also abundantly known in the Chemung group but no names have been applied to them. The accession of material has shown that such Chemung specimens indicate, by one or another set of characters, relations to some of the larger sponges of the group, many of these imperfect fronds probably representing the species *Prismodictya choanea*, *D. Almondensis*, or some similar sponge in which the expanse of surface is large and the prismatic aspect obscured. Thus, also, with most of the described species of ECTENODICTYA; *E. Burlingtonensis* seems a probable representative of the genus LYRODICTYA; *E. expansa* undoubtedly represents a species of THYSANODICTYA and *E. eccentrica**, as now known, is the basal diaphragm of a sponge like PHRAGMODICTYA, but having a structure necessitating its removal to another and new genus, ACLŒODICTYA. There remains, then, but the type-species of ECTENODICTYA, *E. implexa*, whose apparent structure is here described.

ECTENODICTYA IMPLEXA, Hall.

PLATE LIV, FIGS. 3, 4.

1884. *Ectenodictya implexa*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 475, pl. (18) 19, fig. 1.

"Frond a reticulate expansion, assuming a variety of form from pressure or other causes; the original form has been apparently broadly funnel-shaped or ovoid. Base unknown.

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* These species were first described as PHRAGMODICTYA.

"Surface cancellate by strong concentric and vertical striae; the intermediate spaces finely reticulate by filiform striae, which cross each other rectangularly. The body presents prominences or protuberances, which are not sufficiently elevated to be termed nodes.

"A large imperfect specimen, which is distorted by compression, has a length of 180 mm. and a width of about 93 mm.

"The specimens of this species are all more or less distorted; they appear as broad funnel-shaped expansions without evidence of a distinct tubular base, and are usually fragmentary".

The foregoing is the original description of these fossils, founded upon very imperfect material. Upon re-examination of these specimens and comparison with the more completely known species from the Waverly group of Pennsylvania we are disposed to conclude that all are fragments of *Calathospongia Redfieldi* or its close ally, *C. Carlli*. It has already been observed that the cups of these species were very delicate and fragile, easily liable to distortion and fracture; and there are none of the specimens upon which the description of *Ectenodictya implexa* was based which do not show the characteristic expression of the reticulum produced by the predominance of the horizontal spicular bands. The specimen from which the original illustration was drawn, is the apertural portion of a large cup somewhat infolded at the margin. It was incorrectly oriented in the drawing; the right margin represents the apertural edge.

Localities. The specimens have been found in the Waverly group at Warren, Pennsylvania, in association with *Syringothyris Randalli*, and in the same formation at Oil City, in that state.

SPECIES OF THE BURLINGTON GROUP.

LYRODICTYA, Hall.

(For description see page 362.)

LYRODICTYA (?) BURLINGTONENSIS, Hall (sp.).

PLATE LIII, FIG. 6.

1884. *Ectenodictya Burlingtonensis*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 476.

The single specimen representing the only species of Dictyosponge yet found in this formation, consists of a quite imperfect outer impression of a cyathiform frond, having a smooth exterior and showing a strong development

of the vertical spicular bundles toward the base and extending upward in one or two broad and irregular strands. The *reticulum* is fine-meshed and over most of the surface the prevailing quadrule has a diameter of about 3 mm., being frequently subdivided by subordinate series of spicules. The general aspect of the specimen is like that of LYRODICTYA, and the species is therefore provisionally referred to this genus.

Dimensions. Length of the fragment 135 mm., greatest width 130 mm.

Locality. In the yellow sandstone below the Burlington limestone, Burlington, Iowa.

SPECIES OF THE KEOKUK GROUP.

DICTYOSPONGIA, gen. nov.

(For description see page 812, part 1.)

DICTYOSPONGIA CYLINDRICA, Whitfield (sp.).

PLATE LV, FIG. 3; PLATE LXI, FIG. 6.

1881. *Dictyophyton cylindricum*, Whitfield. Bull. No. 1, Amer. Mus. Nat. Hist., p. 19, pl. iv, fig. 3.

1884. *Dictyophyton cylindricum*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 475.

The original specimen of this species is a fragment of a flattened subcylindrical or elongate obconical tube, exposing, for the most part, the inner portions of the reticulum but also showing that the exterior of the sponge was devoid of ornamental features. The exposed surface exhibits fine smooth horizontal and vertical spicular rods disposed at numerous and somewhat unequal intervals in small bundles. The outer or dermal quadrules are formed by cruciform spicules, and measure about .5 mm. on each side. Microscopic examinations of the reticulum reveal among the parenchymalia or dermalia, umbels of a form somewhat different from those in CLEODICTYA, curved diactins and fragments of minute echinate hexactins.

FIGURE 22. Spicules of *Dictyospongia cylindrica*, x400. (J. M. C.)

This species seems to be of rare occurrence; besides the original specimen, there are, in the material in hand, only one or two small fragments, so that the species is still quite imperfectly known. The typical example has a length of 60 mm. and a width of 56 mm.

Locality. In the calcareous shales at Crawfordsville, Indiana.

DICTYOSPONGIA (?) STYLINA, sp. nov.

PLATE LVI, FIG. 2.

Among the material from Crawfordsville is a slender elongate fossil whose sponge nature is strongly suggested by a comparison with the graceful Chemung species, *Dictyospongia lophura.* It is therefore noticed here, although its precise relations may still be somewhat obscure.

The fossil is narrow and subcylindrical, expanding from the basal point to the full diameter of the cup in about one-eighth the length of the specimen. The surface is smooth and covered with fine, closely set vertical lines. The evidence of transverse lines is not very satisfactory; there is, however, a series of comparatively broad and low transverse depressions which are plainly developed over the upper part of the specimen, and these contract toward the upper extremity, producing, with the vertical lines, the effect of an elongate rectangular reticulation. Below this extremity the transverse depressions produce a somewhat undulating surface.

The specimen has a length of 91 mm. and a diameter of about 6 mm. for seven-eighths of its length. There is no evidence of a spicular tuft at the basal extremity.

Locality. In the calcareous shales at Crawfordsville, Indiana.

DICTYOSPONGIA (MASTODICTYA) OSCULATA, sp. nov.

PLATE LVI, FIG. 6.

The figure cited represents one aspect of a sponge of whose complete form it is not possible to obtain an accurate conception from the material in hand. If the peculiar shape presented by it is normal or essentially so, as it seems to be, then this species represents a distinct type of generic structure which, if established by future investigations, may be known as MASTODICTYA; but it is still possible that the shape of the sponge is more or less due to compression or other casual cause. Hence the characters of the fossil are here described from the single example known, while its generic and specific values are left contingent upon the discovery of additional material.

The lower, broken extremity of the specimen has a width of 20 mm. and thence it gradually widens upward into the bulbous swellings. Here the diameter of the cup has increased to 24 mm. The swelling at the right contracts quite abruptly and apparently terminates in an osculum or excurrent orifice at 7 mm. above its greatest diameter; the portion on the left however is much more produced, contracts more gradually, extends to a distance of 23 mm. above the swelling and at the aperture has a diameter of 4 mm.

The general surface is smooth, gracefully expanding to the bulbous swellings, thence sloping with gentle concavity to the oscula.

The *reticulum* is fine-meshed. Since only the outer portion is exposed, the vertical spicular bundles are not visible, but a fragment of a very large rod is seen in the accompanying figure. At the angles of the prevailing quad-

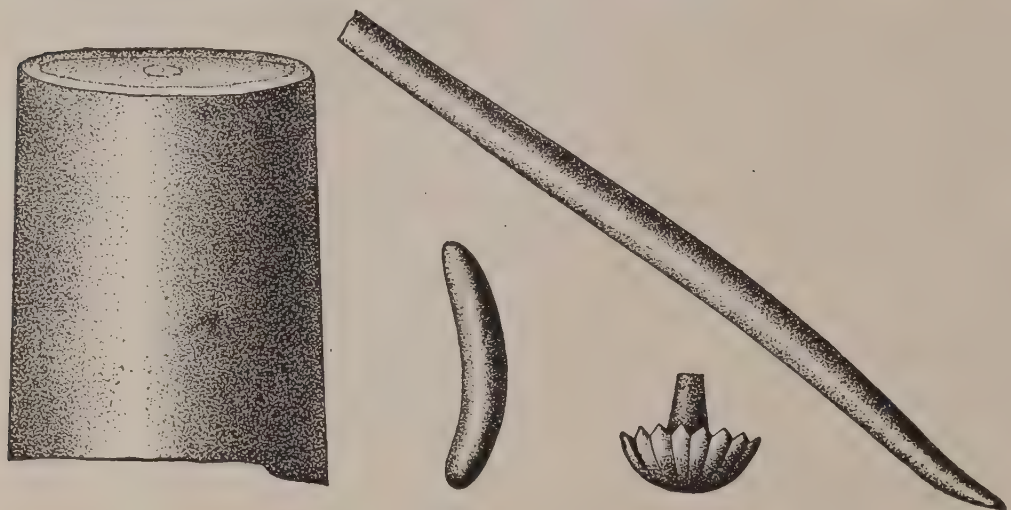


FIGURE 23. Spicules of *Mastodictya osculata*, x400. (J. M. C.)

rules, which measure about 1.5 mm. on a side, there are very strong pentactins or hexactins with modified outer arm, and lateral arms extending for nearly the entire length of the quadrule. An extremital fragment of one of these is represented in the above figure which also shows a many-toothed umbel and a siliquiform diactin.

Locality. In the calcareous shales at Crawfordsville, Indiana.

PRISMODICTYA, gen. nov.

(For description see page 819, part 1.)

PRISMODICTYA POLYHEDRA, sp. nov.

PLATE LV, FIGS. 1, 2.

SPONGE large, subcylindrical, obscurely polyhedral, slightly expanding toward the top. Surface regular and uniformly free of asperities, nodes or protuberances except such as are produced by the slight outward extension of the principal spicular bundles. In the best preserved of the compressed specimens each side bears five broad vertical faces, and at the edges are traces of two more, twelve in all. These prism-faces make low angles with one another, becoming obsolete at the even and regular margin of the osculum.

Reticulum. The quadrate meshes are remarkably uniform in size and arrangement. Assuming that the vertical spicular bands of the first order lie along the angles made by adjoining prismatic faces, a given square of the first order measures about 20 mm. on a side, varying with the slight curvature of the surface, and with the upward expansion of the prism-faces. The subdivision of these quadrules is carried out with regularity to the fifth degree, and even in some of these pentameres there is evidence of a division into ultimate quadrules. Some of the specimens indicate that the surface, in its original condition, was fenestrated by the slight projection of the principal lamellae.

Dimensions. The apertural width of the specimen figured is 120 mm.; its diameter where narrowest is about 90 mm. and the incomplete cup has a length of 115 mm. which was probably somewhat more than one-half its entire length.

Locality. In the calcareous shales at Crawfordsville, Indiana.

LEBEDICTYA, gen. nov.

Large obconical cups, perhaps somewhat unsymmetrical by reason of more rapid growth on one side, probably expanding from a subacute base. Surface obscurely prismatic and cancellated by short projecting spicular lamellae. Aperture crowned by an erect fringe of long marginal spicules.

Type, *Lebedictya crinita*, sp. nov.

LEBEDICTYA CRINITA, sp. nov.

PLATE LVIII, FIGS. 1, 2; PLATE LIX, FIGS. 1, 2; PLATE LXI, FIG. 5.

SPONGE cyathiform, expanding with apparently slight asymmetry from a narrow base. This asymmetrical growth is especially evident in one specimen which not only shows a notable difference in the size of the two sides, but along the apertural margin, which is distinctly retained, indicates a rapid multiplication of the spicular net-work on the longer side of the cup. The surface is rendered obscurely prismatic by the predominance of certain vertical skeletal ridges which, near the aperture, lie about 25 mm. apart. The horizontal ridges do not attain so great size, but the prevailing quadrules are nevertheless large, measuring from 12 to 15 mm. on a side, and are variously subdivided. All these vertical and horizontal spicular bands are erect and form a moderately deep surface reticulation. There may also have been minute tufts at the intersections but the evidence of them is not very clear. The fenestration of the exterior of the cup is similar to, but much less

decided than that in the genus CLATHROSPONGIA, and upon internal casts is much obscured or even lost.

About the aperture the vertical spicules are extended into a long and narrow marginal tuft, apparently a single row of coarse and fine rods (*marginalia*), such as occurs in the living species *Bathydorus fimbriatus*.*

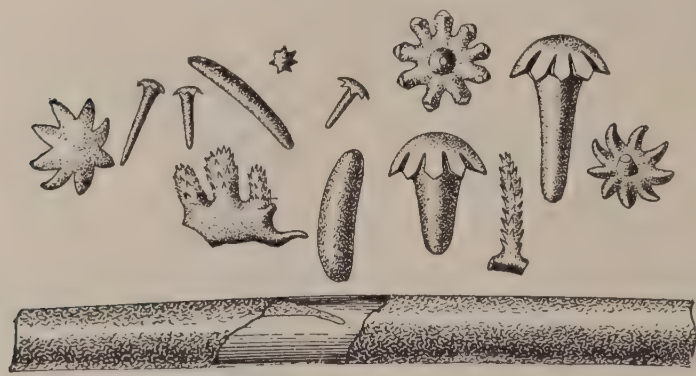


FIGURE 24. Spicules of *Lebedictya crinita*, x400.

The figure at the bottom is a fragment of one of the main rods, partly decorticated; among the others are umbels and micrumbels in various attitudes, smooth diactins, an incomplete tripinulus, etc. (J. M. C.)

In figure 24 are shown some of the skeletal elements of this sponge, the dermalia being represented by umbels, micrumbels, tripinulus and echinate pentactins, and the parenchymalia by smooth siliquiform diactins.

Dimensions. The best preserved specimen, which is incomplete at the lower end, has a length from aperture downward of 155 mm. Its lower diameter is 75 mm.; its apertural diameter in its compressed condition 150 mm. The marginal fringe in some places has a length of 30 mm. A somewhat larger specimen which has been com pressed almost vertically has an apertural diameter of 180 mm.

Locality. In the shales of the Keokuk group at Crawfordsville, Indiana. (Collection of A. S. TIFFANY.)

LYRODICTYA, Hall.

Cyathiform Dictyosponges with regularly expanding, generally smooth exterior, fine net-work, low, erect tufts at wide intervals and very broad, thick vertical bundles of rods and clemes, with no horizontal bundles of corresponding size.

Type, *Lyrodictya Romingeri*, Hall.

LYRODICTYA ROMINGERI, Hall.

PLATE LVI, FIG. 1.

1884. *Lyrodictya Romingeri*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 476.

SPONGE broadly expanding; its form imperfectly known. Surface probably covered originally with low and erect lamellae; ridges with short tufts at

*See SCHULZE, Hexactinellida, pl. lviii, fig. 1.

the angles of some of the quadrules; but in its general aspect smooth, without prism-faces, nodes, or other irregularities.

Reticulum characterized by very broad and strong vertical bundles or *lateralia.* On the exposed surface of the specimen there are seven of these at wide but unequal intervals. These bundles reach almost or quite to the lower extremity of the specimen, spreading gradually outward. An interesting structural feature is the intercalation of other bundles in two of the interspaces at a considerable distance above the base, and both these and the primary bundles increase in width upward. All the bundles are composed of a large number of stout, cylindrical, continuous rods, varying somewhat in size, and with them are numerous clemes of so great size as to be visible to the naked eye. The latter appear to be restricted to the middle and upper extent of the bundles, no trace of them having been found on the lower part of the specimen, and on some of the intercalary bundles they are not to be seen at all. These clemes are similar to those occurring in *Physospongia Dawsoni* and *P. Colleti*, though very much larger. The direction of their teeth is, however, directly the reverse of that in all other known instances. This peculiar fact at first suggested the possibility of an error in the orientation of some of the specimens but repeated reviews of our observations seem to dispel any doubt of their accuracy.

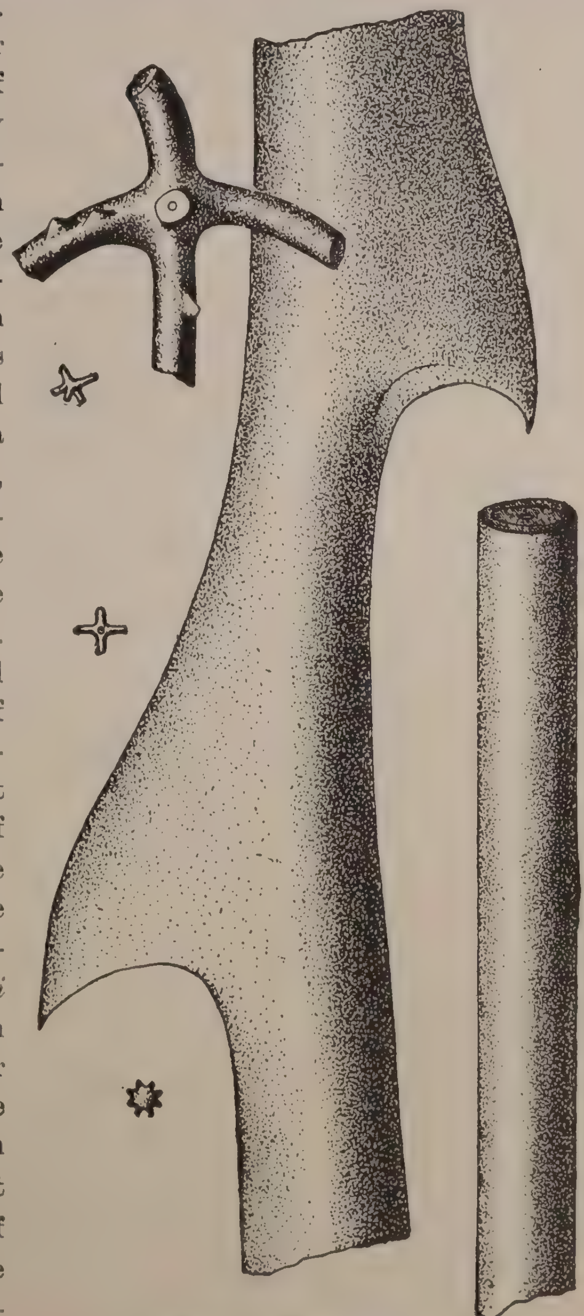


FIGURE 25. *Lyrodictya Romingeri.*
Fragment of one of the large reversed clemes, a diactine rod, cruciform spicules of various sizes and the upper surface of a very small umbel. x400. (J. M. C.)

There are no horizontal bands corresponding with these vertical bundles The rest of the skeleton is pretty much lost; here and there a few interlacing horizontal spicules are to be found at the intersections, but the broad vertical interspaces are regularly divided by impressions of small quadrules which measure from 2 to 3 mm. on a side, without further evidence of coarser markings. At one side of the specimen the edge of the cup is exposed and shows the fact that the interstitial vertical and cross spicules projected for a short distance beyond the surface of the cup, and also that at wide intervals there were small projecting tufts similar to those in PHYSOSPONGIA.

In the matrix taken from the interspaces between the lateralia have been found large echinate hexactins or pentactins with curved arms, also some minute hexactins and micrumbels.

Dimensions. The single known specimen of this species has a length of 98 mm. and a maximum width of 105 mm.

Locality. In the calcareous shales of the Keokuk group, Crawfordsville, Indiana.

PHRAGMODICTYA, Hall.

1881. *Dictyophyton*, Whitfield. Bull. No. 1, Amer. Mus. Nat. Hist., p. 18.

1882. *Phragmodictya*, Hall. Notes on the Family Dictyospongidæ; Expl. pls. 17, 19, 20.

1884. *Phragmodictya*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., pp. 466, 477, 478.

Sub-cylindrical or slightly expanding cups abruptly contracted at the base to form a smooth, broadly obconical or nearly transverse plate or diaphragm. The edge of this basal plate bears a broad peripheral frill. Attachment was probably effected both at the apex of the diaphragm and by the basal frill. Surface covered with vertical ridges and nodes. Reticulum very fine and without tufts.

Type, *Phragmodictya catilliformis*, Whitfield (sp.).

This genus differs from THYSANODICTYA in the absence of a coarse regular quadration and fenestration of the surface and in the distinctly radiate network of the basal diaphragm, and from ACLŒODICTYA in the convergence of the radial bands of the diaphragm to a well-defined and probably tufted apex.

PHRAGMODICTYA CATILLIFORMIS, Whitfield (sp.).

PLATE LXIV, FIGS. 1–5; PLATE LXV, FIGS. 1, 2; PLATE LXVI, FIGS. 1–9; PLATE LXVII, FIGS. 1–4; PLATE LXVIII, FIGS. 1–4.

1881. *Dictyophyton catilliforme*, Whitfield. Bull. No. 1, Amer. Mus. Nat. Hist., p. 18, pl. iii, fig. 1.

1882. *Phragmodictya scyphus*, Hall. Notes on the Family Dictyospongidæ. Expl. pl. 17, figs. 12, 13; pl. 19, figs. 2, 3; pl. 20, figs. 1–6.

1884. *Phragmodictya catilliformis*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 477, pl. 18, figs. 12–14; pl. 20, figs. 2, 3; pl. 21, figs. 1–6.

SPONGE sometimes of large size but usually of medium proportions; subcylindrical or with a somewhat flaring aperture; base broad, slightly expanded, its diameter increased by the projection of the periloph. General form stout, the length being less than twice the median diameter. Specimens having the aperture clearly retained show a slight contraction of the upper margin but it is not fully determined whether this is a normal feature.

The base is a very shallow obcone with a slightly eccentric apex; its margins appear to make an angle of about 1108 with the lateral walls of the cup, and its converging surfaces to be gently concave except about the apex.

Vertical walls of the sponge generally devoid of ornament except for a series of irregularly disposed vertical ridges and elongate nodes. These lie at subequal intervals and occasionally a single ridge may be traced for nearly the full length of the cup. The nodes seldom occur about the base, while they multiply toward the top, the ridges sometimes being resolved into a series of disconnected nodes, but frequently the ridge-like nodes appear in the interspaces between the ridges, and without order or arrangement. At the edge of the basal disc the ridges are abruptly transsected, making the margin nodose, as it is in the genus THYSANODICTYA. The surface of the periloph shows a more or less regular continuation of the ridges. The surface of the basal obcone or disc is wholly smooth and in this respect is in marked distinction to the generally exposed or vertical walls of the cup.

Mode of attachment. The convergence of the vertical spicular bands to the apex of the basal diaphragm and the usual imperfection of this apex are evidences of the attachment of the sponge at this point. Such attachment, however, was restricted to the apex of this obcone, and though similar to that in most of the Dictyosponges here considered, would have been inefficient in holding the sponge firmly in position. It is evident that important accessory

aid was contributed by the spicular bands of the periloph extending downward beyond the periphery of the disc. This extension bears in some degree the ornamental features of the lateral walls of the cup and many of the stronger spicular bundles of those walls were continued into it. The terminal or lower edge of the periloph is not regular, but where the ridges come down from above it is produced into short radiciform extensions.

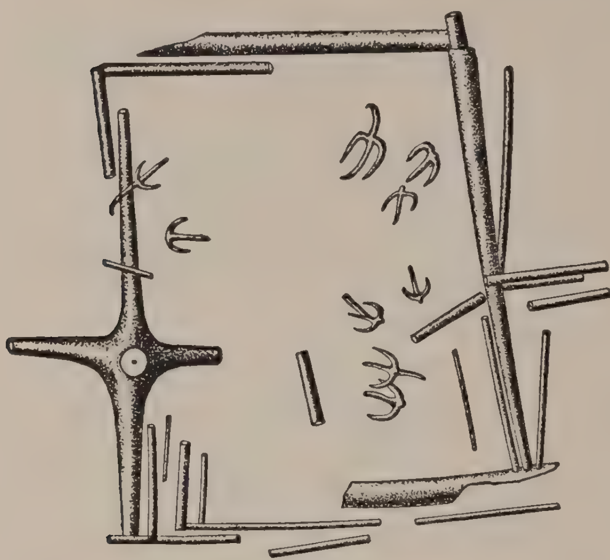
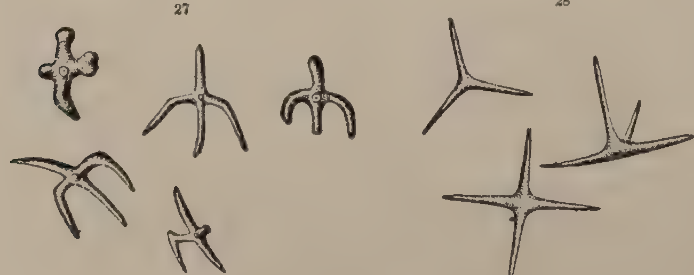


FIGURE 26. *Phragmodictya catilliformis.*
A minor mesh bounded by rods and pentactins, with curved pentactins or hexatins over the interspace. (J. M. C.)

Reticulum. The net-work of the sponge is exceedingly fine, and the subdivision very uniform. There are no strong bands of vertical or horizontal rods, and it is often difficult to find traces of them except near the base. On the surface of the basal obcone, however, the vertical or rather radial bands are very distinct, while the horizontal or concentric bands are less so.

Skeleton. The search for the spicular elements of the skeleton has shown that the rhabdus of the gastral and anchoring spicules are small and few in comparison with the other species whose spicular structure is known. The fine texture of the reticulum is due to quadrules, which for the most part, seem to be outlined by strong hexactins at the angles, their arms overlapping (fig. 26). These have long, smooth and acute branches. There also appear to have been pentactins or hexactins of great size with echinate arms, as indicated by the large fragment shown in figure 29, but had they been abundant we should probably know more of their form. The only other spicules of notable size are indicated by the slender fragments bearing long spinules, shown

27 28



FIGURES 27, 28. Spicules of *Phragmodictya catilliformis*, x400.
In figure 27 are curved pentactins like those seen in figure 26. In one of these spicules the arms end in knobs.
Figure 28 shows other modifications of the parenchymal spicules. (J. M. C.)

in the same figure. These may be parts of large pinuli, or still another style of cruciform spicule. Characteristic of this species are the curious pentactins or hexactins with curved arms, which lie scattered abundantly among the quadrules (see figs. 26, 27). Other modifications of the pentactin are shown in figs. 28 and 30. Considerable diversity of form is found among the diactins; some are elongate, pod-shaped, some stout and bean-shaped, others have a strong single curvature or a double curve. A few fragments have been seen which indicate diactins with clavate or spherical extremities.

FIGURE 29. Fragments of echinate spicules of *Phragmodictya catilliformis*, x400. (J. M. C.)

These are represented in figure 30. The only trace of anchorate spicules observed is a minute form shown in the same figure.

The elements of the skeleton, taken as a whole, are quite distinct from those of the other species here described. The umbels and clemes, characterizing the genera PHYSOSPONGIA, CLEODICTYA, LYRODICTYA, etc., seem to be wholly wanting.

Dimensions. This species, which is the most abundant of all the forms occurring in the Crawfordsville shales, varies greatly in size. A young and essentially entire individual which probably retains the proportions normal for full growth, has a slightly curved cup, its length from the aperture to the distal edge of the periloph measuring 60 mm. The width of its aperture is 50 mm., its median diameter is 28 mm., and its basal width about 25 mm., the periloph having a length of 5 mm. A nearly entire specimen of average size, slightly incomplete at the aperture, has a length of 95 mm., the periloph is 15 mm. in length where longest, and the apex of the basal obcone is 9 mm. below the plane of its base. The largest cup observed has an apertural diameter of

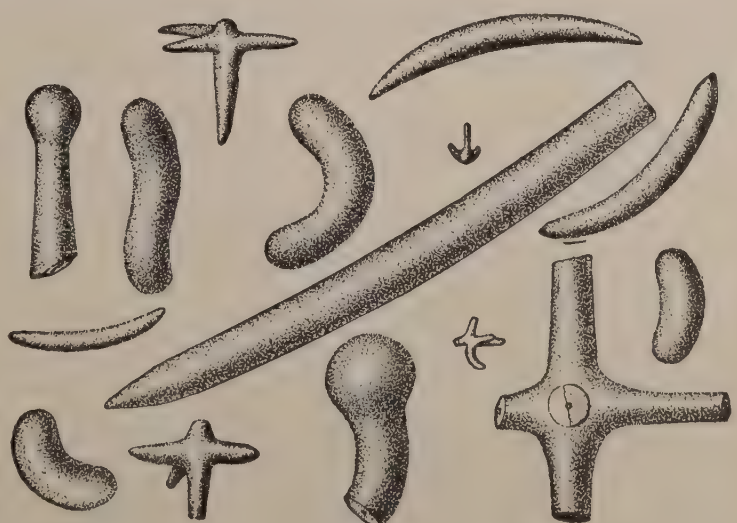


FIGURE 30. Spicules of *Phragmodictya catilliformis*, x400. Here are shown various forms of diactine and cruciform spicules, and among them is a small anchorate clavule. (J. M. C.)

230 mm. A basal diaphragm, 140 mm. in greatest diameter, bears a frill 45 mm. in width.

Locality. Keokuk group. In the calcareous shales, and rarely, in the overlying sandstone, at Crawfordsville, Indiana.

PHRAGMODICTYA PATELLIFORMIS, Hall.

PLATE LXV, FIG. 3.

1884. *Phragmodictya patelliformis,* Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 478.

The original specimen of this species is a large oval basal obcone with a highly eccentric apex. Its major diameter is 132 mm. and the apex lies 32 mm. from the nearest margin. The minor diameter through the apex is 100 mm., through the center 115 mm. The impressions of the radiating spicular bundles are strong, and the surface of the plate, which has been preserved in a calcareous nodule with its contour undisturbed, is gently convex. The aspect of this basal disc is unlike that of *Phragmodictya catilliformis,* in its much more eccentric apex and convex surface.

Locality. Keokuk group. In the calcareous shales at Crawfordsville, Indiana.

PHRAGMODICTYA (?) CREBRISTRIATA, Hall.

PLATE LXI, FIG. 4.

1884 *Phragmodictya (?) crebristriata,* Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., pl. 21, fig. 7.

This fossil which has been illustrated in the place cited but not before described, appears to be an impression of a part of the flaring aperture of a Dictyosponge with an extremely fine reticulum, or part of an outer mould of a basal obcone with obscure nodes at the periphery. The radial spicular impressions, though fine, are distinct, while the reticulating bands are highly obscure. It probably represents a species unlike any of the others here described, but its generic characters are still uncertain.

Locality. Keokuk group. In the calcareous shales at Crawfordsville, Indiana.

(?) PHRAGMODICTYA LINEATA, Hall.

PLATE LXVIII, FIG. 5.

1884. *Phragmodictya lineata,* Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 478, pl. 21, fig. 8.

This name was given, in the work cited, to an imperfect specimen of a small subcylindrical cup, with moderately coarse reticulation and a surface

devoid of the ornamental nodes and ridges occuring in *Phragmodictya catilliformis.* The specimen was described as having an oblique, convex basal cone with a strong eccentric cicatrix, but upon a reexamination this supposed structure seems to be a portion of the lateral wall of the cup which has been broken and somewhat irregularly compressed. The characters of this specimen are not retained with sufficient clearness to demonstrate its specific value.

Locality. Keokuk group. In the calcareous shales at Crawfordsville, Indiana.

ACLŒODICTYA, gen. nov.

1882. *Phragmodictya*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 19, fig. 1.

1884. *Ectenodictya*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 476.

Subcylindrical sponges with strongly fenestrated exterior, as in CLATHROSPONGIA, and with abruptly obconical base, as in PHRAGMODICTYA. There is no periloph as in the latter genus and in THYSANODICTYA, and the vertical

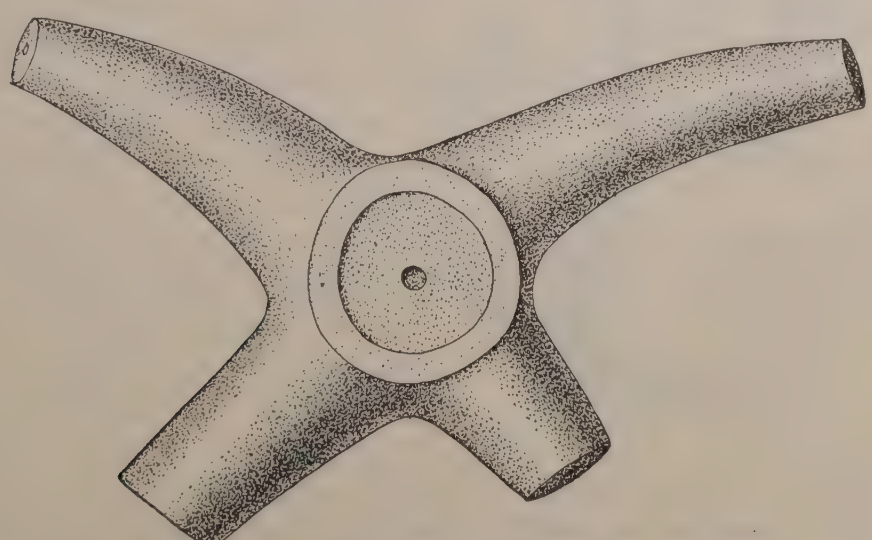


FIGURE 81. Large hexactin or pentactin of *Aclœdictya marsipus*, x400. (J. M. C.)

spicular bands converge irregularly to or about a broad apical point. The radial bands from one side are continuous across the disc and are reticulated by another set of radial bands from the other two quadrants of the disc.

Type, *Aclœodictya marsipus*, sp. nov.

ACLŒODICTYA MARSIPUS, sp. nov.

PLATE LV, FIGS. 4, 5; PLATE LX, FIGS. 3–5; PLATE LXI, FIGS. 1–3; PLATE LXVIII, FIGS. 7, 8.

SPONGE robust, elongate, subcylindrical. Basal obcone, when uncompressed, expanding at an angle of about 50 degrees; continuing for not more than one-fifth the length of the cup, whence the surface, with a sharp but not angular bend, becomes abruptly erect in its growth. Near the basal disc the cup is at first broadly constricted, thence upward gradually expands and again narrows to the aperture. Thus the form of the sponge is that of a broad, medially inflated tube resting upon a shallow obcone.

Reticulum. The vertical and horizontal strands form meshes which are divisible into various series, though, with the usual preservation of the fossil, these differences are obscure. The primary series form quadrules which are about 10 mm. on each side, and these are divided by subordinate series in the usual manner Over the body of the sponge, both horizontal and vertical spicular bands were produced into erect reticulating lamellae which form a series of fenestrated areoles. The broadest of these lamellae may have a margin of 5 mm. A single poorly preserved specimen in which a portion of the pyritized skeleton is retained shows the presence of very large anchorate basalia with broadly divergent, smooth flukes and convex head. There are also great pentactins with curved arms, and clemes with short intervals between the acuminate lateral processes. These are forms similar to those occurring in PHYSOSPONGIA and CLEODICTYA. A peculiar pentactin (or tetractin) with short club-shaped arms, a form not observed in other species, occurs here among the parenchymalia. A figure is also given of a very small pentactin with long, straight and simple arms.

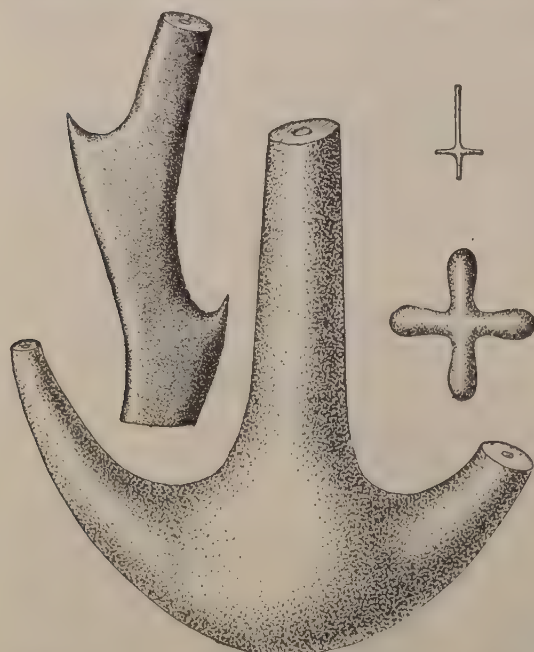


FIGURE 32. Cleme, anchorate clavule and stauractins of *Aclœodictya marsipus*, x400. (J. M. C.)

Dimensions. The largest and best preserved example, in which the sponge is compressed but essentially entire, has a length of 140 mm.; length

of basal obcone, 30 mm.; diameter at base of the cylindrical portion, 70 mm., at the middle, 85 mm.; at the aperture, 75 mm.

Localities. In the calcareous shales at Crawfordsville and Indian Creek, Indiana. (Largely from the collection of A. S. TIFFANY.)

ACLŒODICTYA (?) ECCENTRICA, Hall (sp.).

PLATE LIV, FIGS. 1, 2.

1882. *Phragmodictya eccentrica*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 19, fig. 1.

1884. *Ectenodictya eccentrica*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 476, pl. 20, fig. 1.

This species was based upon certain discoid bodies, marked by irregularly radiating and concentric spicular impressions, which converge about the central area. The aspect of the specimens suggests the basal obcone in *Aclœodictya marsipus*, but the reticulation is much finer than in that species and the surface toward the periphery shows undulations with a tendency to plication. Two of the specimens indicate that a portion of the vertical or radiating spicules from opposite quadrants of the disc are continuous over the apical region, while they are crossed by the spicules from the other quadrants, the radial spicular bands thus reticulating with each other. The concentric or horizontal bands also appear to be present on this apical area. No cicatrice is observable in the specimens.

The specimens which represent this species differ considerably in size, one having a semidiameter of 50 mm., the other of 80 mm. The entire diameter of another is 55 mm.

Locality. In the calcareous shales at Crawfordsville, Indiana.

GRIPHODICTYA, gen. nov.

Elongate subcylindrical sponges with subequally expanded base and aperture. No diaphragm or basal disc present (?).

Surface smooth. Reticulum very fine. Skeleton bearing a great number of hexactins with modified arms (oxyhexasters) and umbrella-shaped clavules of various forms.

Type, *Griphodictya epiphanes*, sp. nov.

The external characters of this sponge are not fully known, but its spicular composition is so totally unlike that of other forms that upon this

character both genus and species are founded. Sufficient is also known of the shape of the body to permit its recognition from the accompanying description.

GRIPHODICTYA EPIPHANES, sp. nov.

PLATE LV, FIG. 6.

SPONGE slender, originally subcylindrical or with the tube gently expanding to both extremities, the incurvature of the vertical walls being a

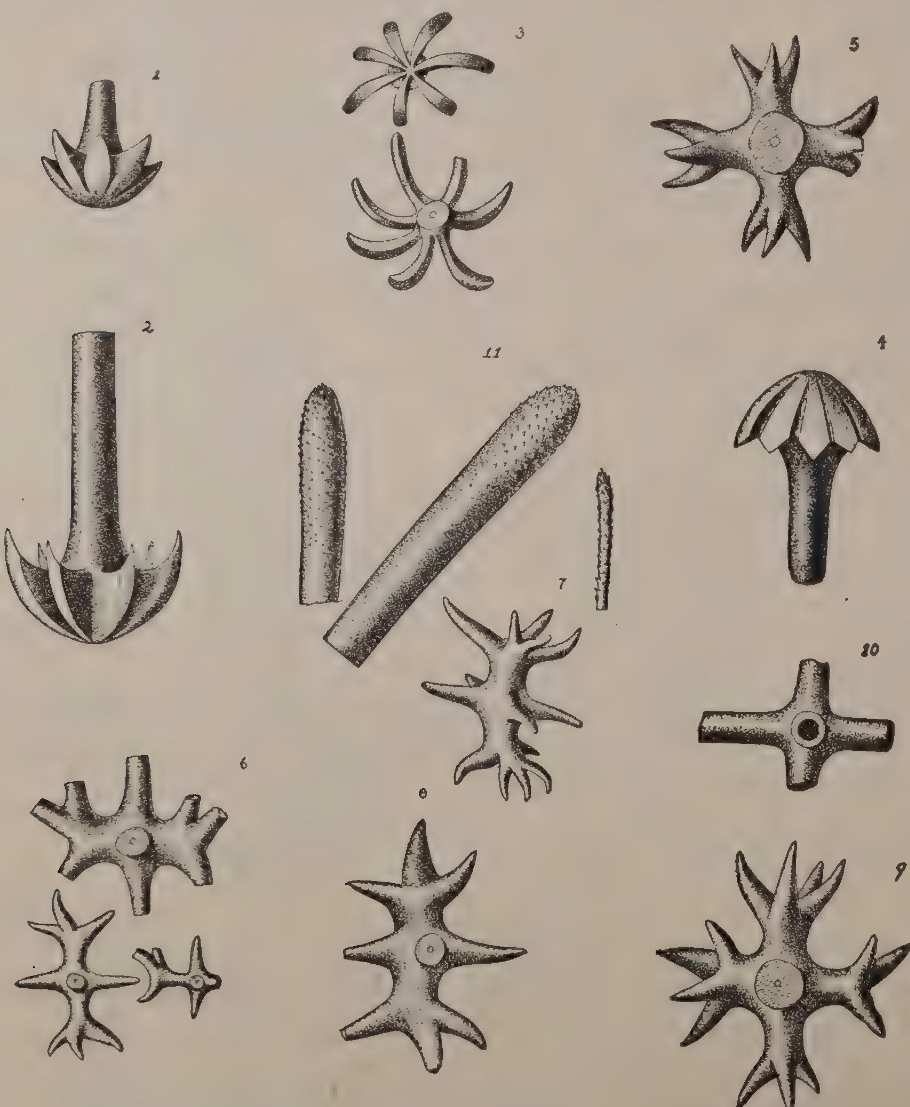


FIGURE 63. Spicules of *Griphodictya epiphanes*, x266. 1-4, umbels of different form; 5, oxyhexaster with the arms divided into three prongs each; 6, 7, 8, oxyhexasters with the arms of the horizontal axes unmodified and the others variously branched; 9, oxyhexaster with four prongs on two of the arms and three on the other two; 10, simple hexact or pentact; 11, fragments of echinate spicules. (J. M. C.)

very broad arc without interruption throughout its extent. The base of the sponge terminates abruptly in a broadly undulated margin by which attachment was evidently effected or aided, as in the case of the periloph of PHRAG-

MODICTYA. Apertural region somewhat more expanded than the base; margin of aperture regular and without tufts. Surface smooth, or with traces of obscure, discontinuous vertical ridges.

Reticulum very fine. The specimen is so preserved as to expose for nearly its entire length the inner surface of the wall, this being somewhat abraded about the base. At the summit a portion of the internal cast adheres, so that the entire thickness of the skeleton is here retained. Toward the lower part of the sponge may be seen remnants of two small, widely separated vertical bundles of stout smooth rods. No other vertical rods are apparent, while the horizontal rods, though minute, are so abundant and so matted together as to form a felt of spicules without any division into bundles. The prevalence of these quite obscures all traces of reticulation. The flesh spicules, which are extremely abundant over the upper part of the specimen, are large oxyhexasters with their rays variously modified; sometimes four of these rays are simple, while those of the third axis are divided each into three prongs; in other cases the rays of a single axis are simple and those of the other axes divided into three or four prongs. The prongs are not always of the same number in a hexaster, some of the rays bearing three, some four, and the prongs themselves being variously subdivided and often producing very complicated forms. There is some variation in size in these spicules as shown in the accompanying figures. Besides these hexasters, which seem to compose the greater part of the spicular mass, there are occasional fragments of regular hexactins, and numerous fragments of hexactin rays showing very finely echinate extremities. There are also two styles of umbrella-shaped clavules, one having a sharply tapering head with broad divisions, eight in number, the other considerably larger, with apparently seven highly divergent, narrow and acuminate divisions.

The specimen bears no little resemblance to a small, or young individual of *Phragmodictya catilliformis*, though showing no evidence of basal plate or frill, and it was regarded as that species until the examination of its skeletal structure demonstrated the impropriety of referring it either to this or any other known species of Dictyosponges.

Dimensions. Length, 54 mm.; basal width 20 mm.; median width 15 mm.; apertural width 25 mm.

Locality. In the calcareous shales at Crawfordsville, Indiana.

CALATHOSPONGIA, gen. nov.

(For description see page 347.)

CALATHOSPONGIA AMPHORINA, sp. nov.

PLATE LXVIII, FIG. 6.

SPONGE small, abruptly and broadly expanded at the aperture; body comparatively short, subcylindrical, having considerably less than one-half the width of the aperture; basal portion somewhat expanded, probably terminating abruptly. Surface without ridges, nodes or other irregularities.

Reticulum composed of very fine spicular bands, producing uniformly small meshes. On the internal cast there are no sharply defined quadrules but there is a notable predominance of the vertical spicular bundles which are individualized near the base but in ascending they become broadened and diffuse.

The single specimen has its flaring apertural portion bent over upon the body of the cup, but the original form of the sponge is very clearly shown. Part of the base is missing but the slight expansion of the cup in this region indicates a stout and abrupt termination.

Dimensions. The diameter of the aperture in the specimen described is 54 mm.; that of the body of the cup at the base of the aperture, 20 mm., and the entire length of the specimen 70 mm.

Locality. In the calcareous shales at Crawfordsville, Indiana.

CALATHOSPONGIA (?) MAGNIFICA, sp. nov.

PLATE LVI, FIG. 5; PLATE LVII, FIG. 1.

SPONGE of large size, funnel-shaped, probably subcylindrical about the body, rapidly and abruptly expanding toward the aperture. Form incompletely known. Surface more or less obscurely prismatic and without nodes or other irregularities.

Reticulum divided into large quadrules by horizontal intersections with the obscure prism-edges or spicular ridges corresponding therewith. These quadrules measure about 24 mm. on a side, over the body of the cup, but widen considerably toward the aperture. There are four or five subsidiary series of meshes in each quadrule of the first order, the reticulation of the entire surface being thus complete and regular. Probably the principal spicular bands were more or less elevated into erect lamellae.

Dimensions. We have represented two large fragments of this species, both showing the expanded upper portion and a part of the body of the cup. The larger of these has a length of 240 mm., a width below of 140 mm., and at the upper end the diameter, if entire, would be about 300 mm. The second specimen is smaller and shows a somewhat more rapid expansion of the cup. Both of these specimens have been compressed. Fragments of the species are not uncommon but are usually very imperfect.

Locality. In the calcareous shales at Crawfordsville, Indiana.

CLEODICTYA, Hall.

(For description see page 355.)

CLEODICTYA GLORIOSA, Hall.

PLATE LXIX, FIG. 1; PLATE LXX, FIGS. 1, 2.

1884. *Cleodictya gloriosa*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 479.

SPONGE large, urceolate in form; rapidly expanding from a probably broad and flattened base into the single basal row of nodes, where it attains its greatest width; above this it is abruptly contracted, thence gradually expands with a smooth surface and graceful outward curvature toward the aperture. From the summit of the nodes downward, which was less than one-half the length of the cup, the surface is gently convex; above them the surface is concave.

The nodes are large, strongly convex, obtuse, wider vertically than horizontally and are directed obliquely upward resting on the crest of a horizontal ridge produced by the constriction of the cup. The number of these nodes is somewhat variable; the finest example bears ten of about equal size and shows an additional but incipient node in one of the dividing grooves. A second and smaller specimen has eleven fully developed nodes with an incipient twelfth. These facts indicate the probability of increase in the number of nodes with the growth of the individual as well as their numerical variation in different individuals. The external cast indicates that the nodes were not tufted nor any other part of the surface elevated into spicular lamellae. The grooves separating the nodes are broad and moderately deep, not, however, interrupting the general elevation of the ridge upon which the latter rest.

Shortly above the upper base of the nodes the surface contracts for about one-fourth the lower diameter of the cup, and its gradual expansion from this point upward continues, it is believed, without interruption to the aperture;

thus making the upper part of the sponge regularly vase-shaped with a circular cross-section. The actual extent of this vase and the precise form of the aperture remain unknown.

The *reticulum* is fine-meshed throughout and in no place is there evidence of conspicuous reticulating bands, the aspect of the net-work being very similar to that in species of CALATHOSPONGIA (e. g. *C. Redfieldi*, *C. Carlli*). The larger quadrules are minutely subdivided and vary in size and form as the curvatures of the surface vary. The fossil is in a sandstone and the spicules are not preserved.

This magnificent sponge attained commanding dimensions. The best of the specimens, which has lost something from each extremity, has a height of 190 mm. It has been somewhat compressed laterally and its greatest width at the lower end is 145 mm.; its width across the basal nodes is 215 mm. At its narrowest diameter, above the nodes, it measures 120 mm., and at the top about 140 mm. A smaller specimen representing the basal portion only, measures 115 mm. across the row of nodes.

Locality. From a sandstone of the age of the Keokuk group, overlying the calcareous shales at Crawfordsville, Indiana. (Collection of E. B. HALL.)

CLEODICTYA MOHRI, Hall.

PLATE LXX, FIG. 3.

1884. *Cleodictya ? Mohri*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 479.

SPONGE elongate, swollen below, broadly constricted and gradually expanding above. The base is broad and the expansion thence to the hori. zontal row of nodes is convex and rapid. This expanded portion of the sponge is relatively much longer than in other species of the genus, the nodes themselves being very obscure, elongate and but slightly elevated. Over one portion of the elevation on which they lie, where the reticulum is fully preserved, they are scarcely discernible. On the exposed half of the cup there are evidences of four nodes with a possible fifth. Above the nodiferous expansion, the contraction of the cup is gradual

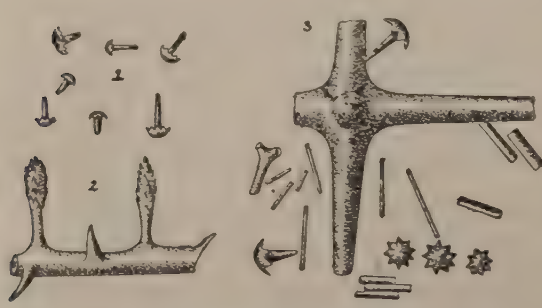


FIGURE 34. Spicules of *Cleodictya Mohri*.
1, Group of umbels, x60; 2, compound pinulus, x200; 3, hexactin surrounded by umbels and fragments of rhabds, x50. J. M. C.)

for one-half the remaining distance, thence upward the expansion begins again and is continued to the aperture.

The *reticutum* is smooth and in its general aspect like that of *C. gloriosa* and *C. Claypolei*. Over the upper portion of the cup there is a series of

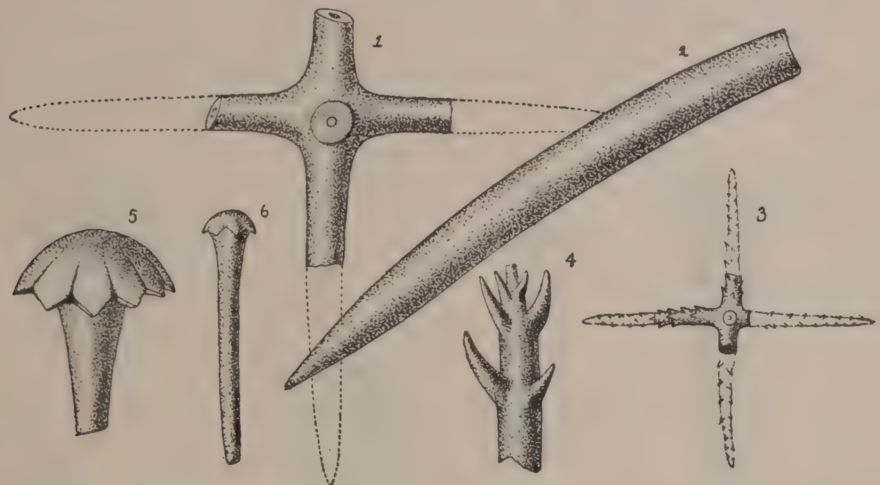


FIGURE 85. Spicules of *Cleodictya Mohri*, x400. 1, large hexact; 2, extremity of rhabd or hexact; 3, echinate hexact; 4, extremity of large echinate hexact; 5, umbel; 6, micrumbel. (J. M. C.)

horizontal bands of spicules which are more conspicuous than the rest and are not crossed by vertical bands of corresponding size at regular intervals.

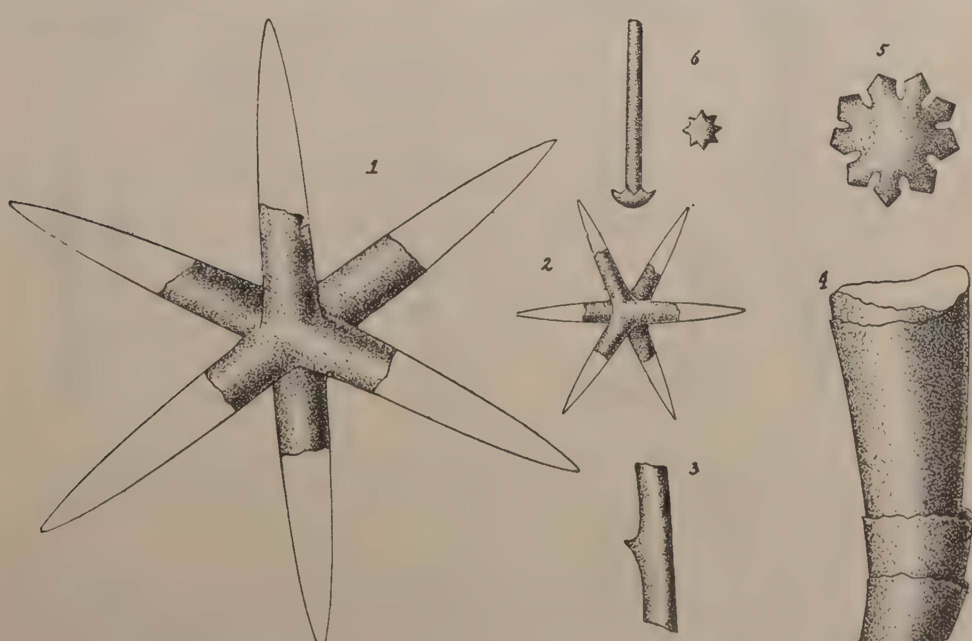


FIGURE 86. Spicules of *Cleodictya Mohri*, x400. 1, 2, hexacts; 3, small cleme; 4, rhabd showing concentric layers; 5, 6, umbel and micrumbel. (J. M. C.)

Above the basal expansion the vertical bundles of spicular rods or rhabds lose their close definition and are spread over the quadrules somewhat to the

obscuration of the latter. There is much variation in the size of these rods, large and small ones being bundled together. In figure 37 is shown the terminal portion of one such rod. A close examination seems to establish the fact that the majority of these *lateralia* terminate before reaching the basal expansion and those which continue to the base of the cup are mainly the rods of largest diameter. The horizontal bundles are of similar size, but individual rods are frequently as large as any occurring in the vertical

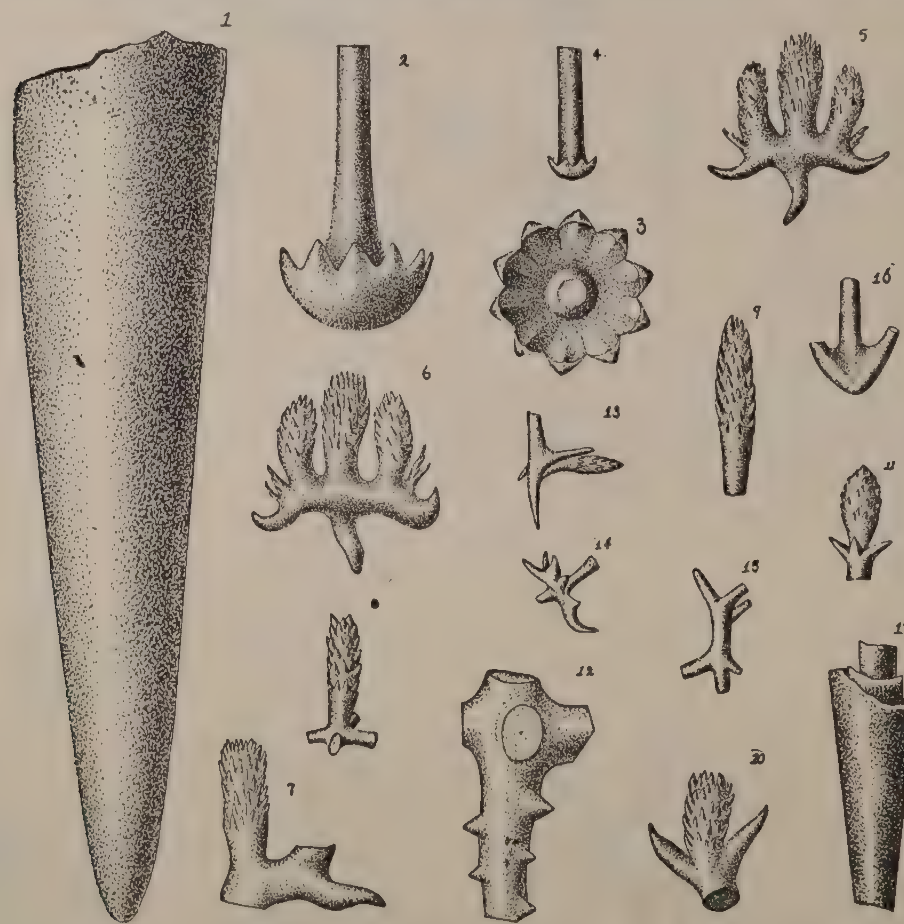


FIGURE 37. Spicules of *Cleodictya Mohri*, x400. 1, Terminal portion of vertical rod ; 2, umbel ; 3, the same from beneath ; 4, micrumbel ; 5, 6, the two sides of an entire tripinulus ; 7, 9, 10, 11, 13, various fragments of pinulus forms ; 8, incomplete amphiaster ; 12, echinate hexact , 14, 15, *spiculæ innominatæ* ; 16, anchorate clavule , 17, rhabd showing concentric layers. (J. M. C.)

series. The ultimate quadrules, which measure about .5 mm., have at each angle regular hexactins whose arms traverse more than one-half the length of the contiguous squares, the extremital portions of adjacent spicules overlapping. The outer vertical arm is sometimes modified into a blunt node. Such hexactins are shown in figures 34, 35 and 36. There are also other regular hexactins of large and small size with echinate arms, as shown by the frag-

ments represented in figure 35. The smaller of these probably belong to the parenchymalia but the larger has not been located.

There is a very considerable variety in the forms which may be referred to the parenchymalia and dermalia. Perhaps the most striking of these are the large and small umbels (umbels and micrumbels; figs. 34, 35, 36 and 37). These are like the dermal clavules which have been figured by F. E. SCHULZE in the recent species *Farrea occa*,* except that here the shafts are always short and smooth, gently swollen beneath the umbels, and the teeth of the umbels smooth. They evidently have nothing to do with the anchoring spicules or basalia, and the same is probably true of the anchor-shaped fragment shown in fig. 37 (16) which was taken from the upper part of the cup. To the dermalia may also be referred the peculiar compound tri-pinulus, both sides of the complete form of which are shown in figure 37 (5, 6). The morphology of this spicule is not readily apprehended. There are also other peculiar pinulus forms as shown in figures 34 (2) and 37 (7, 9, 10, 11, 13), which are as yet incompletely known. In figure 37 (8) is an imperfect amphiaster belonging to the parenchymalia.

Dimensions. The original specimen measures 130 mm. in height, 70 mm. in diameter at the base, 100 mm. across the nodose expansion, 65 mm. where narrowest, and about 75 mm. at the upper end which is imperfect.

Locality. In the calcareous shales at Crawfordsville, Indiana.

PHYSOSPONGIA, Hall.

1881. *Uphantænia*, Whitfield. American Journal of Science, vol. xxii, p. 132.

1881. *Uphantænia*, Dawson. American Journal of Science, vol. xxii, p. 132.

1881. *Uphantænia*, Whitfield. Bull. No. 1, Amer. Mus. Nat. Hist., p. 15.

1882. *Physospongia*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 19.

1884. *Physospongia*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., pp. 467, 479–481.

The fossils of this genus have the form of a diminutive basket with broad strands and coarse meshes. The upright body has a very gradual expansion from the base upward and its surface was probably regular, as far as appears from the usual mode of preservation, though it is possible that, when compressed, the strong vertical strands of the spicules may have given it a somewhat prismatic form. Normally the surface bears two series of these vertical

* Hexactinellidae, pl lxxi, figs. 3, 5, 9.

spicular bands, one broad and conspicuous, its members alternating with a series of narrow bands. In the type-species, *P. Dawsoni*, where all generic features are most clearly defined, these bands are generally placed at equal intervals, but there may be in other cases, and even in this species, considerable variation in this respect. By the crossing of the concentric or horizontal spicular bands, which are narrow, of equal breadth and nearly equidistant, the area enclosed by any two of the broader vertical bands is divided into subequilateral quadrules, and each of these quadrules is again divided into four quadrules by the intersection of a vertical band of the second order with a horizontal band. Of the four quadrules thus formed two are elevated into bullate expansions or pouches, the other two are depressed into regularly concave basins; nodes and depressions alternating in position so that normally every node is surrounded by four depressions and every depression by four nodes, each at the same time being separated from every other by spicular bands. Considerable irregularity in the disposition of these elevated and depressed areas is sometimes shown by *P. Colletti*, while the little known *P. multibursaria* in this structure quite fails to conform with our conception of the genus.

As usually preserved the tops of the surface nodes are broken off, or by adherence to the matrix give the impression of a vertical series of areoles, but normally the surface of these nodes and depressions is continuous and finely reticulated by regularly disposed interlacing pentacts. All specimens observed have been more or less subjected to compression and it is possible to ascertain the full elevation of the nodes only along the edges of the cup. In such marginal sections we also find evidence of extensions from the horizontal spicular bands into slender erect tufts. These always occur at the intersection of the horizontal and vertical bands, and it is probable that they were developed at every such intersection. The spicules of the vertical bands do not appear to have been complicated with those of the horizontal bands in the formation of these tufts.*

There is certainly a striking similarity in external structure between PHYSOSPONGIA and the great explanate or saucer-shaped bodies already described as HYPHANTÆNIA, and which occur in the form of impressions in the sandstones of the Chemung group. Our knowledge of HYPHANTÆNIA is still incomplete but we know that the intervals between the vertical and horizontal or concentric spicular bands were partially if not wholly covered by spongin.

* In the brief original description of this genus these tufts were regarded as originating from the summits of the nodes.

Similar skeletal structure is also to be found in the genus ROEMERISPONGIA of the middle Devonian of Germany (*R. Gerolsteinensis*, F. Roemer; see part 1, page 807).

In American faunas species of PHYSOSPONGIA are known only from the Keokuk group, all specimens having been derived from the calcareous shales in the vicinity of Crawfordsville, Indiana.

PHYSOSPONGIA DAWSONI, Whitfield (sp.).

PLATE LXII, FIGS. 1–10.

1881. *Uphantænia Dawsoni*, Whitfield. American Journal of Science, vol. xxii, 3d ser., p. 132.

1881. *Uphantænia Dawsoni*, Whitfield. Bull. No. 1, Amer. Mus. Nat. Hist., p. 15, pl. iv, figs. 1, 2.

1882. *Physospongia Dawsoni*, Hall. Notes on the Family Dictyospongidæ; Expl. pl. 19, figs. 4–6, 8 (not fig. 7).

1884. *Physospongia Dawsoni*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 479, pl. 19 (20), figs. 4–6, 8.

SPONGE subcylindrical over the body and lower portion, expanding somewhat more rapidly toward the aperture. In the majority of specimens the cup seems to taper quite rapidly toward the base, but the base itself was evidently broadly obtuse, and in some instances slightly expanded. This portion of the cup is seldom retained. Size comparatively small, rarely exceeding a length of 75 mm. with a nearly equal width at the aperture when under compression. As usually preserved the width of the cup at the upper end is about one third greater than at the lower end; occasionally the former is twice that of the latter.

Reticulum. The primary reticulation of the surface is very coarse and is produced by a double series of vertical spicular bundles intersecting a single series of horizontal bands. Of the vertical bundles the principal series is broad and flat, its width being from three to five times that of the secondary series. There is a notable increase in width from below upward in the principal bundles, as occurs in *P. Colletti.* The principal and secondary vertical bundles alternate in position and are equidistant, the latter equally dividing the area set off by the former. The horizontal bands are narrow, carrying about the same number of spicular rods as the secondary vertical bundles. The intersection of these with the principal vertical bundles divides the surface into equal quadrules, each of these being sub-divided into four equal

parts by the intersection of the horizontal with the secondary vertical bands. Two of the quadrules thus formed are elevated into regular convex pouches or nodes, the other two are concave, and it seems probable that the curvature of the concavity was originally equal to that of the node. These elevations and depressions alternate in position and thus each node is surrounded by four depressions and each depression by four nodes. The general surface effect produced by this arrangement is that of a series of double vertical rows of nodes separated by the broad vertical spicular bands. The number of the primary vertical bands is usually twelve, though some specimens seem to have had not more than ten.

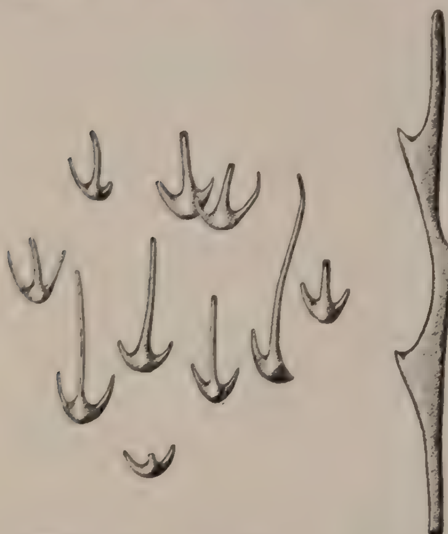


FIGURE 38. *Physospongia Dawsoni.* A group of anchors and a sleme. x60. (J. M. C.)

Growth. The younger parts of the specimens usually show a diminution in the size and in the development of the surface nodes and depressions, and when the actual basal parts of the cup become known they probably will be found comparatively free of the usual surface conformation. Near the apertural margin also the nodes become less distinct, that is, less elevated, though often of greater area. The duplication of the nodes and depressions as an accompaniment of growth in the expansion of the cup, such as occurs frequently in *P. Colletti*, is very rarely observed in this species.

Skeleton. In the remarks already given upon the structure of the skeleton of the thin-fleshed Dictyosponges, it has been observed that the tuft of basal spicules or basalia is but a continuation and union of the long vertical spicular bundles which, with the horizontal bands, produce the characteristic reticulation of the surface. Further evidence from analogy with living hexactinellids, as well as from the facts themselves, is that these lateralia or upward extensions of the basalia lay within the sponge and probably bounded the surface of the great gastral cavity. The flesh-wall of the sponge, however, was so exceedingly tenuous that in the best preserved of the DICTYOSPONGIDÆ it is usually extremely difficult to distinguish the gastral from the dermal surface as far as shown by differences of structure.

In *Physospongia Dawsoni* the innermost or true gastral surface of the principal lateralia bears only long cylindrical rods, varying notably in size. These may frequently be followed for the length of two or three quadrules

without interruption, and probably were originally continuous to the base of the sponge. The upper or outer portions of these spicular bundles contain numerous small cylindrical rods which terminate in a two-pronged anchor, each barb or prong tapering backward toward the aperture into a slender rod ending in a point. The head of the anchor is considerably inflated on the smooth surfaces and its apex or point is blunt. The size of the anchors varies somewhat, as shown in the accompanying figure, both enlargements to the same degree. These anchorate spicules are scattered, often abundantly, throughout the entire length of the lateralia and could have had nothing to do with the fixation or anchoring of the sponge.

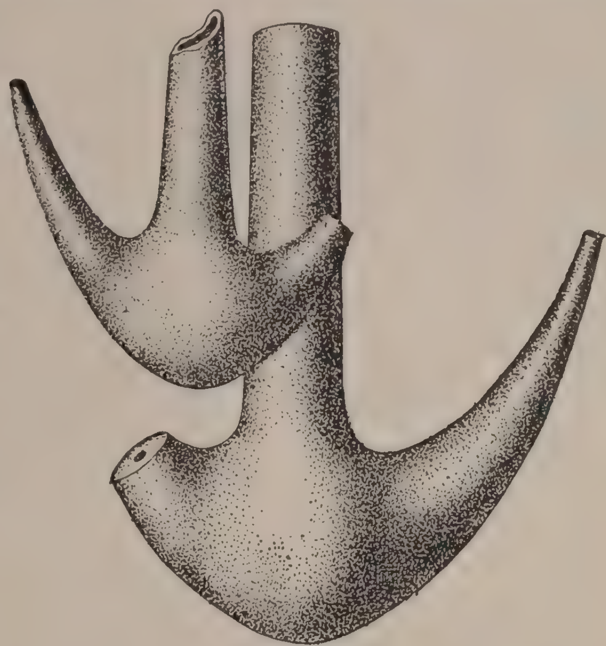


FIGURE 39. *Physospongia Dawsoni.* The heads of two anchorate spicules. x400. (J. M. C.)

Together with the anchorate spicules or just above them and on the outermost layer of the bundles, is a series of parallel twigs or clemes which have been described as somewhat flattened rods expanded alternately first on one lateral margin and then on the other, into elongate triangular surfaces whose outer or marginal angle is acute and continued a short distance backward into a very slender rod-like extension. Between this and the edge of the spicules the margin of the triangle is gently incurved. The intervals between the triangular expansions vary somewhat, and the spicules themselves are generally more slender than the rods of the gastral surface, though they are seen to be of considerable length. One specimen, which happens to be the original of *Uphantœnia Dawsoni*, Whitfield, is so broken that a portion of these vertical bundles remains on the interior or gastral cast and the rest or outer portion on the enclosing rock. The former of these fragments is figured by WHITFIELD

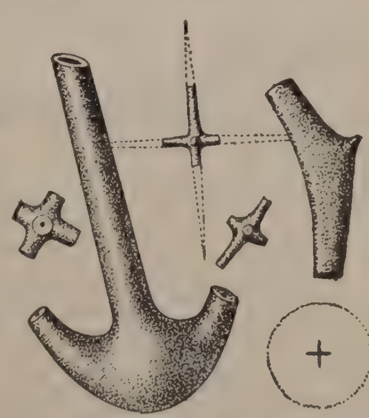


FIGURE 40. *Physospongia Dawsoni.* A group of spicules. The stauractin in the circle is enlarged 30 diameters; the others 250 diameters. (J. M. C.)

(loc. cit. fig. 1). The separation is of such a nature that only the cylindrical rods adhere to the gastral cast while the anchorate spicules and clemes are beautifully displayed in their original position upon the enveloping matrix. The secondary vertical lateralia and the horizontal reticulating bands are composed of comparatively few cylindrical spicules, some of which attain a greater size than any observed in the principal lateralia, but neither of these series has shown any trace either of the anchorate or of the clemate spicules.

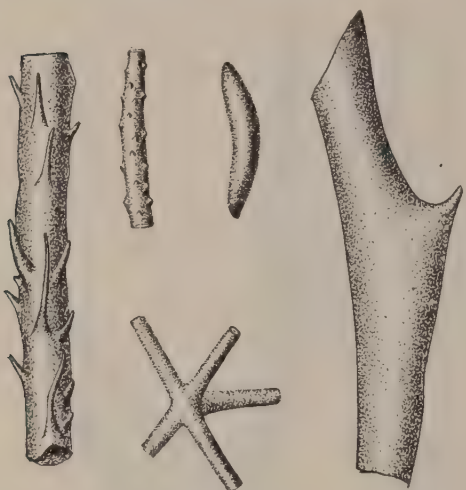


FIGURE 41. Spicules of *Physospongia Dawsoni*, x400. Fragments of echinate hexacts, a smooth-rayed pentact, a diact and part of a cleme. (J. M. C.)

Mention has been made of the radiate tufts produced by the extension of the horizontal spicular rods at their intersection with the vertical lateralia of both series. The spicules of the horizontal lateralia appear to lie nearer the gastral surface than do the principal and secondary vertical bundles. At the intersection of the horizontal and vertical bundles are occasionally seen large pentacts, sending a ray along each bundle departing from that point, the fifth ray passing inward. These pentacts are the heaviest parts of the skeleton, and as they lie above or outside of the lateralia they probably belong to the dermal surface.

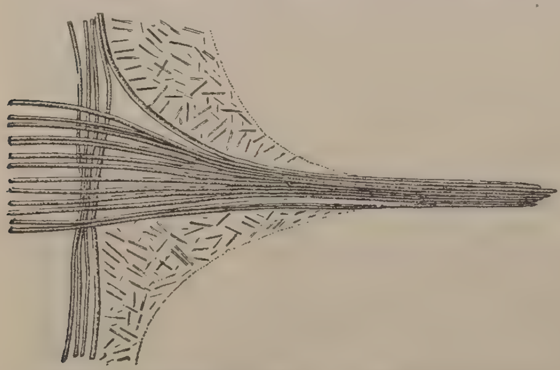


FIGURE 42. *Physospongia Dawsoni*. A somewhat diagrammatic figure of one of the spicular tufts. x10. (J. M. C.)

The dermal surface of the quadrules formed by the intersection of the lateralia is regularly and very finely reticulated by smooth-rayed pentacts lying in apposition. These vary in size but are never more than one-tenth as large as the smooth pentacts at the intersection of the lateralia. Among the spicules which evidently belong to the parenchyma of the sponge are numerous fragments of echinate branches, some of which undoubtedly are parts of echinate hexacts, as that represented in figure 41. The same figure shows a fragment of a large spicule in which the surface spinules are more produced than in any of the echinate spicules of other species. This form of spicule seems to be of rare occurrence in the species, and from analogy with *P. Colletti*, *Cleodictya*

gloriosa, and other species, we have to conclude that it belongs to a large hexact or pentact whose precise position in the skeleton still remains in doubt.

Smooth, elongate siliquate diacts (figure 41) of small size are occasionally found among the parenchymalia.

After careful search this species has afforded no evidence of umbels such as occur in *P. Colletti and Cleodictya gloriosa.* Nevertheless it seems probable that they exist, though they may be of great rarity.

Dimensions. The size of this species, in comparison with its closest ally, *P. Colletti*, is always small. An individual of rather large dimensions has a length of 70 mm., an apertural diameter of 80 mm., and a basal diameter of 30 mm. Fragments of somewhat larger examples have been observed. An average specimen which seems to be complete, is 45 mm. in length, has a basal width of 50 mm., contracting above this to a width of 44 mm. and expanding again to an apertural diameter of 60 mm.

Locality. Physospongia Dawsoni is known only from the calcareous shales of the Keokuk group at Crawfordsville and Indian Creek, Indiana.

PHYSOSPONGIA COLLETTI, Hall.

PLATE LXIII, FIGS. 1–7.

1884. *Physospongia Colletti*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 480, pl. xx, fig. 7.

SPONGE large, rapidly, and sometimes unsymmetrically expanding from a broad base to a wide aperture.

Surface highly nodose, similar in structure and aspect to that of *P. Dawsoni*, but with nodes of much greater size, and with more frequent irregularities in their arrangement.

Reticulum. The primary and secondary vertical bundles are of very unequal size. The former are broad and compact over the lower portion of the sponge but become diffuse above, spreading into a fan-like brush near the aperture and obscuring thereby some of the main quadrules. Over the median and lower portion of the cup the quadrules are nearly square but toward the aperture both nodes and concavities become transverse, the horizontal diameter increasing and the vertical diameter lessening, until each division becomes very narrow. Thereupon ensues a multiplication in the number of vertical rows of nodes and depressions, the two rows of any one of the main vertical divisions of the surface increasing to four, and the area occupied by each large node or depression over the body of the cup bears two small nodes and corresponding depressions. This duplication of the vertical rows of quadrules is

shown in figs. 5 and 6 of the plate cited. The aperture of the cup appears to be smooth and its margin regular and even, without processes or spicular projections.

Skeleton. As in *Physospongia Dawsoni*, the vertical bundles in this species are composed of a great number of smooth rods, there being associated with them anchors and clemes. In the material under examination the spicular structure is not very satisfactorily retained, but it would seem as if these anchorate and clemate rods were comparatively less abundant than in *P. Dawsoni*, and they prove to be of somewhat smaller size. The predominant pentactins are of large size and strongly echinate. It is presumed that these lay at the angles of the quadrules and their abundance is in contrast to the comparatively rare occurrence and small size of similar bodies in *P. Dawsoni*. The surface of the nodes and depressions is very minutely and retangularly reticulated but so little of the spicular framework over those areas has been preserved that only the large umbel (fig. 44) can be referred thereto. It has been observed that although the specimens of *P. Dawsoni* have afforded much more satisfactory means of studying the spicular elements of the skeleton, no umbels have been found in that species. Presumably in *P. Colletti* spicular tufts were present at the intersection of the

FIGURE 43. Spicules of *Physospongia Colletti*: fragments of clemes, anchorate clavules and echinate hexactins, etc. x65. (J. M. C.)

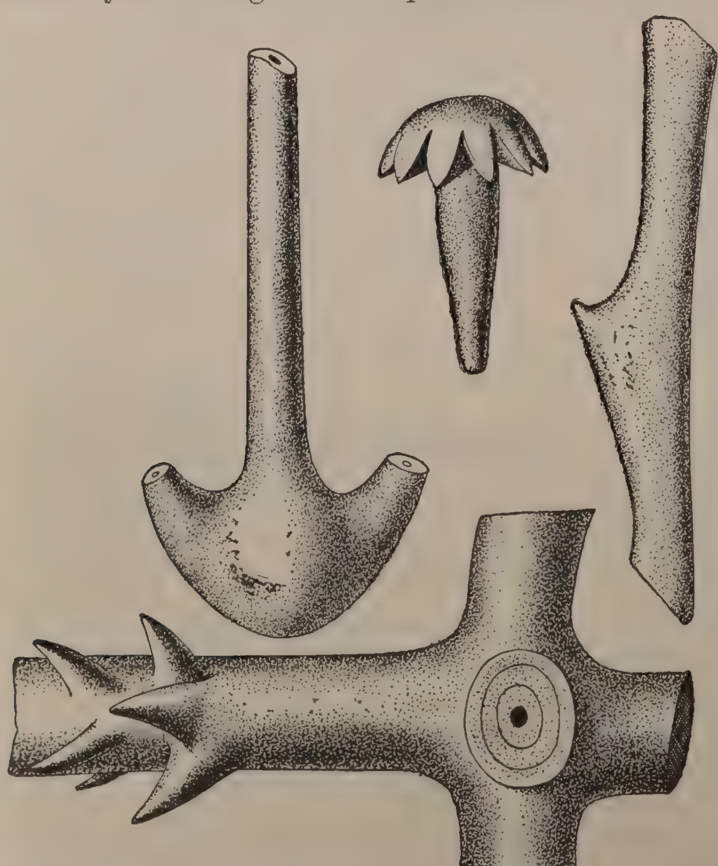


FIGURE 44. Spicules of *Physospongia Colletti*. x400. (J. M. C.)

horizontal and vertical spicules, as in *P. Dawsoni*, but no satisfactory evidence of them has been observed.

Dimensions. A specimen which preserves the upper portion of the cup for a length of 82 mm. has an apertural width of 150 mm. and a diameter at the lower end of 80 mm. Another example which represents the basal and median parts of the sponge, is 90 mm. long, 105 mm. wide at the top, and 55 mm. wide at the base. Both of these specimens have been laterally compressed.

Locality. In the calcareous shales at Crawfordsville, Indiana.

PHYSOSPONGIA ALTERNATA, Hall.

PLATE LXII, FIG. 11.

1882. *Physospongia alternata*, Hall. Notes on the Family Dictyospongidæ. Expl. pl. 19, fig. 9.

1884. *Physospongia alternata*, Hall. Thirty-fifth Ann. Rept. N. Y. State Mus. Nat. Hist., p. 481, pl. xx, fig. 9.

The few specimens of this species which have been observed show a narrow subcylindrical tube with a length of about 40 mm. and a width of 25 mm. That these undoubtedly represent a specific form distinct from the others here described is shown, first, in the subequal width of the vertical lateralia, and second, in the comparatively slight development of the alternating elevated and depressed quadrules.

The vertical and horizontal spicular bands are narrow, subequal in width, about equally distant from one another and hence the quadrules formed by their intersection are nearly square. The number of double rows of squares is but six at the lower part of the specimen, but towards its upper part there is a duplication of one of the rows by the development of a new vertical spicular bundle, such as frequently appear in *P. Colletti*. It has not been possible to fully investigate the spicular skeleton of this sponge. Some of the vertical lateralia bear clemes similar to those of the other species of PHYSOSPONGIA, but no anchorate rods have been observed. Large pentacts lie at the angles of the meshes and small pentacts and smooth-rayed hexacts are found over the quadrules.

Locality. Keokuk group, Crawfordsville, Indiana.

PHYSOSPONGIA MULTIBURSARIA, sp. nov.

PLATE LXI, FIG. 7.

This is an aberrant form, referred to the genus PHYSOSPONGIA, pending a more complete knowledge of its structure. The single specimen represents a portion of one side of what must have been a very large sponge of whose original proportions it is not possible to form an accurate conception. The surface is flat and measures 175 mm. in length and 110 mm. in its greatest diameter. This expansion is covered with a great number of small, rounded elevations having the form of drooping pouches, the smaller of them resembling the nodes of *Physospongia Dawsoni*, but the longer appear to have been of the pendulous nature of the lobes in BOTRYODICTYA though of much smaller size. These nodes are arranged in vertical rows although there are portions of the surface where the order is somewhat obscured by the overlapping of

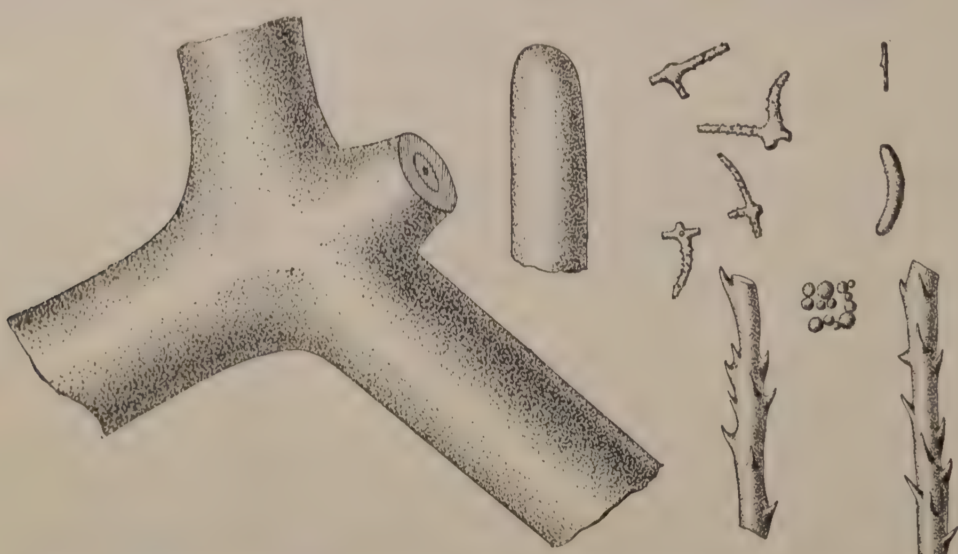


FIGURE 45. Spicules of *Physospongia multibursaria*, x400. Showing a large irregular pentact, fragments of echinate hexacts, smooth diact and a minute cleme. (J. M. C.)

the longer nodes. At the bottom of the specimen, thirteen of these rows may be counted, while toward the top, where the surface is broadest, there are as many as twenty. No arrangement into transverse rows can be distinguished.

A few of these processes show traces of reticulation about their basal portions or over their summits, but where the interspaces are uncovered or the nodes have been removed, the impression of a fine spicular net-work is everywhere seen. The unbroken marginal portion at the right of the specimen is without nodes, and here the reticulum is partially preserved in pyrite.

The meshes and spicular bands appear to be in two not very clearly marked series, the principal bands, so far as can be seen, being from 3 to 5 mm.

apart which is the width of the nodes. The bands themselves are extremely narrow. There is no such prominent development of bundles of lateralia as in the typical species of PHYSOSPONGIA, a fact which, of itself, is suggestive of probable different generic relations in this species. Some small portions of the skeleton which have been submitted to microscopic examination show very large pentactins with blunt extremities, such as are shown in figure 45. These were probably at the junction of the larger transverse and horizontal bands. There are also small, echinate pentactins or tetractins, some larger fragments indicating similar spicules of more conspicuous size, and small sausage-shaped diactins. The little cleme represented in the figure shows the extreme minuteness of certain elements of the skeleton. Throughout the mass examined are clusters of minute spheres of pyrite, which at first impression would seem of concretionary origin; it may, however, be possible that these are modified spicules (diactins ?). No evidence has been found of the umbels (clavules), anchors and plumes of *Physospongia Dawsoni.*

Locality. In the soft shales of the Keokuk group, Crawfordsville, Indiana.

EXPLANATIONS OF PLATES.

PLATE XLVIII.

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLIX, L, LI, LII, LVI, LVII, LX, LXVIII.)

CALATHOSPONGIA REDFIELDI, Hall (sp.).

Page 347.

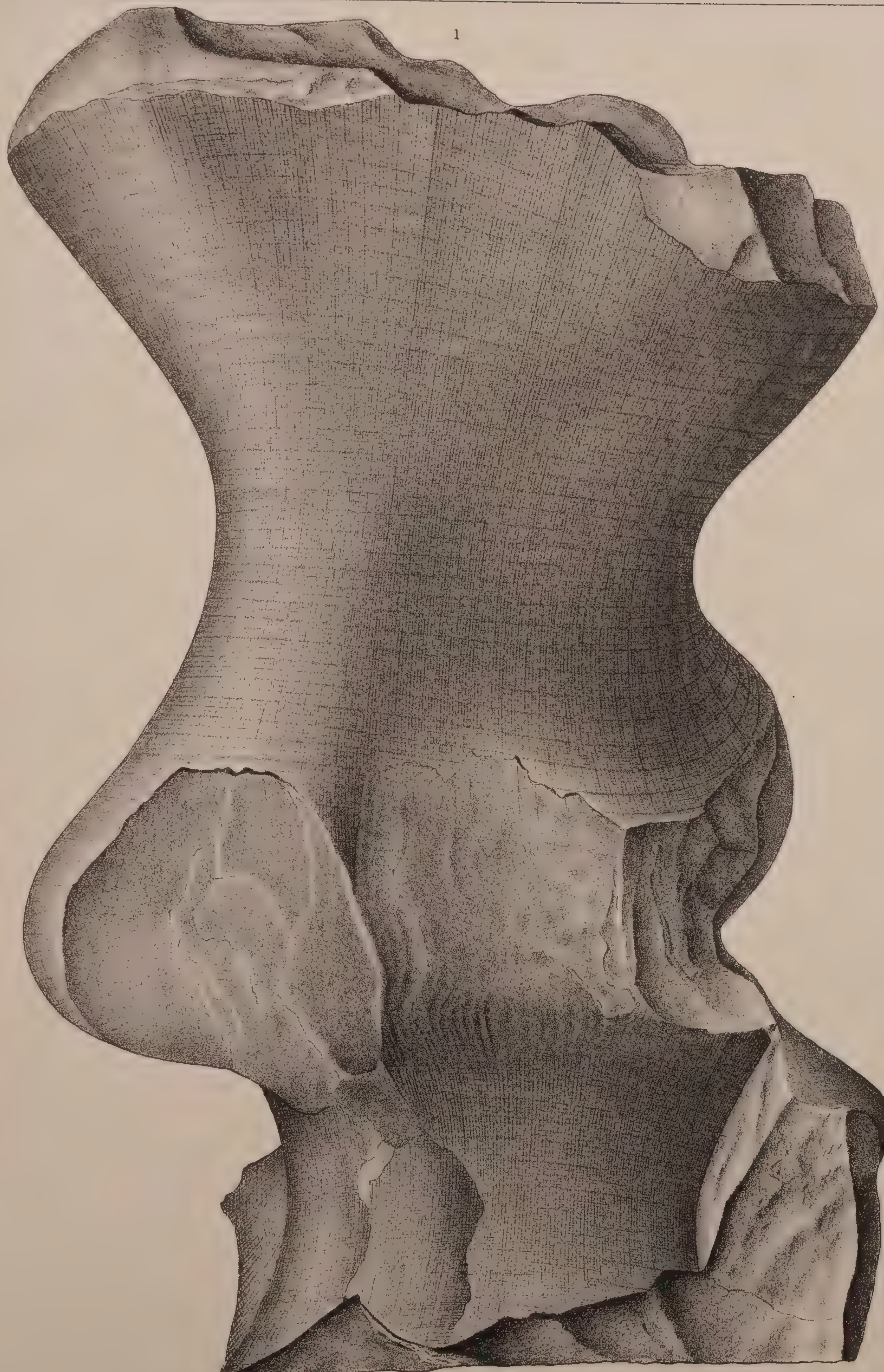
(See Plate XLIX.)

Figures 1, 2. Opposite sides of a fine, large, nearly entire sponge, with the aperture complete on one side. The median swelling of this cup seems to be due to distortion from vertical compression, and the base, though not actually retained was probably not greatly different from the present condition of the lower extremity. The specimen shows the characteristic surface features with great clearness, and over the apertural region as well as upon the swollen portion of the cup in fig. 2 may be seen obscure traces of the prismatic faces.

Waverly group. *Akron, Ohio.*

DICTYOSPONGIDÆ.

1



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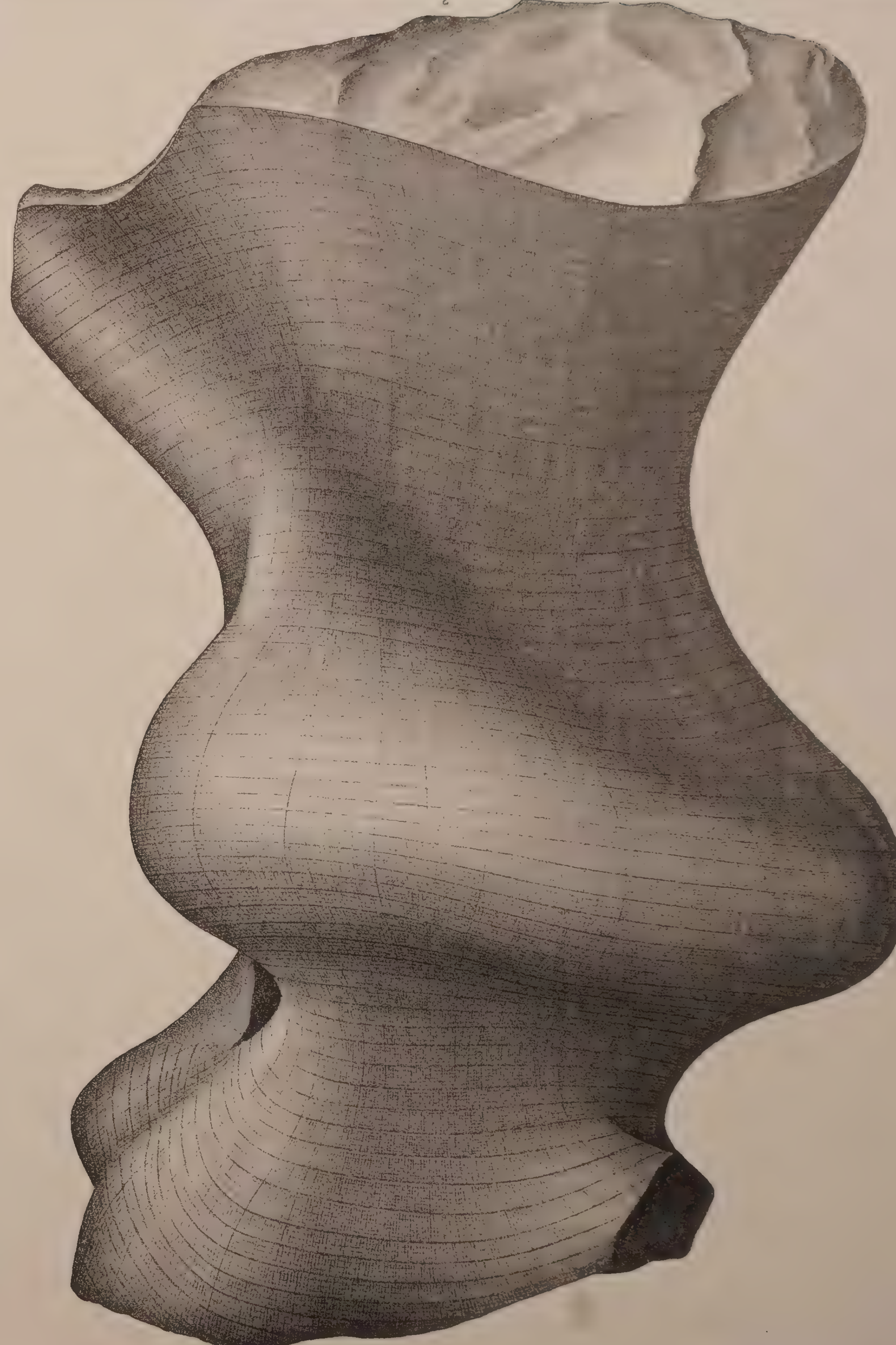

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PLATE XLIX.

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLVIII, L, LI, LII, LVI, LVII, LX, LXVIII.)

CALATHOSPONGIA REDFIELDI, Hall (sp.).

Page 347.

(See Plate XLVIII.)

Figure 1. A fragment of a small specimen
Waverly group. *Richfield, Ohio.*

Figures 2, 3. The opposite sides of a specimen which is virtually entire, the apertural portion having been distorted by the vertical compression and rupture of the reticulum. The surface of this specimen has been somewhat abraded on the side shown in fig. 2, and the primary transverse bands of the reticulum are not as clearly displayed as in the example represented on the preceding plate. In fig. 3, the finer superficial net-work is predominant.

Figure 4. An enlargment of the surface from the same specimen, taken from near the top of the side shown in fig. 3. These figures are from the type-specimen of the species.
Waverly group. *Harrisville, Ohio.*

CLATHROSPONGIA, Hall.

Page 861, part 1.

(See Plates XIV, XV, XVIII, XXI, XXV, XLIX, L.)

CLATHROSPONGIA ABACUS, Hall.

Page 345.

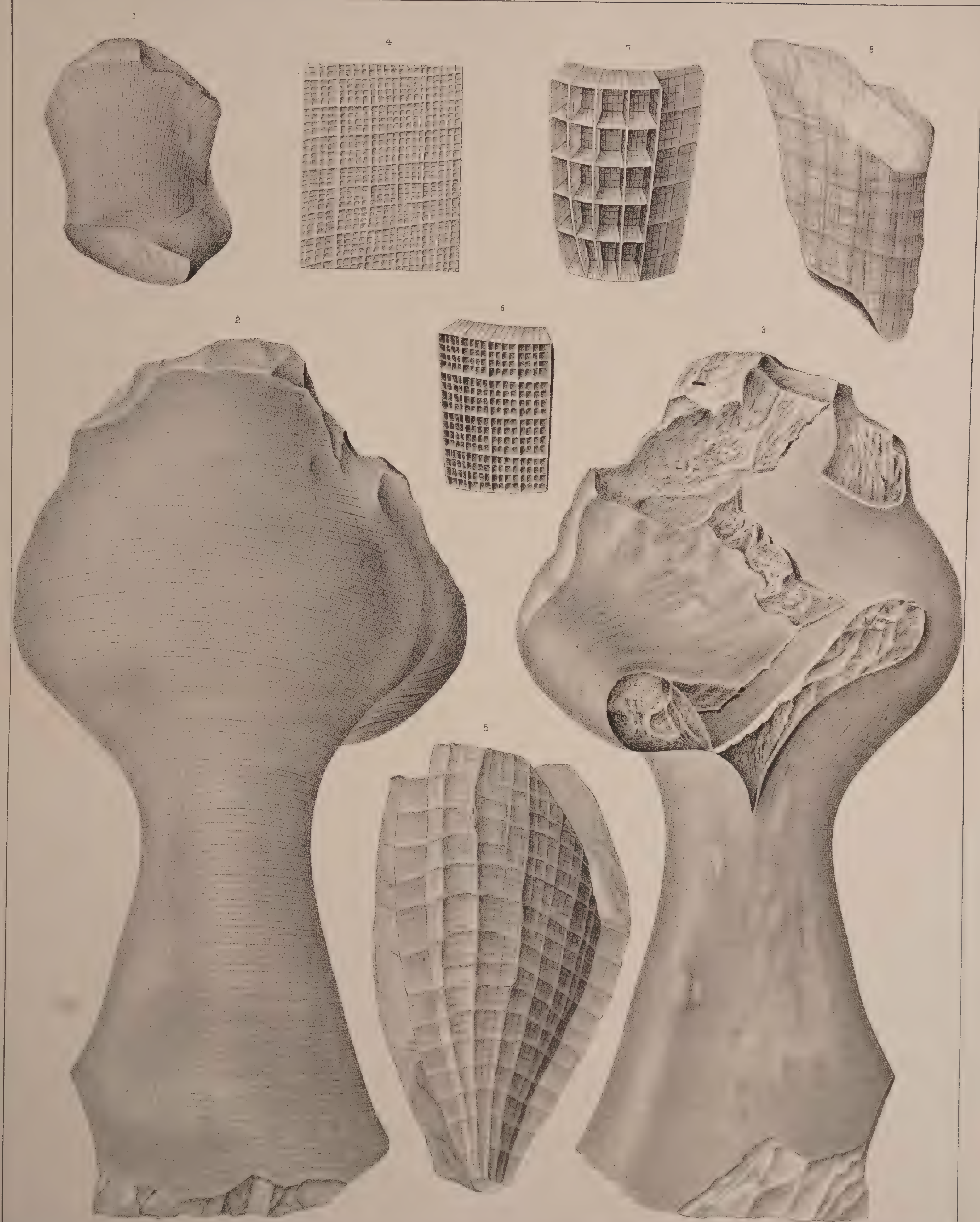
Figure 5. A nearly complete individual which shows the obconical form of the cup and the great development of the erect vertical and horizontal spicular lamellae.

Figure 6. A restoration of a segment of the surface showing the relative development of the successive series of reticulating lamellae, which produce a deep fenestration of the outer sponge-wall.

Figure 7. A restoration showing only the primary vertical and horizontal bands with the marks of subordinate lamellae upon their surface.

Figure 8. An internal cast showing the aspect of the fossil when divested of its exterior lamellae.
Waverly group. *Warren, Pennsylvania.*

DICTYOSPONGIDÆ.



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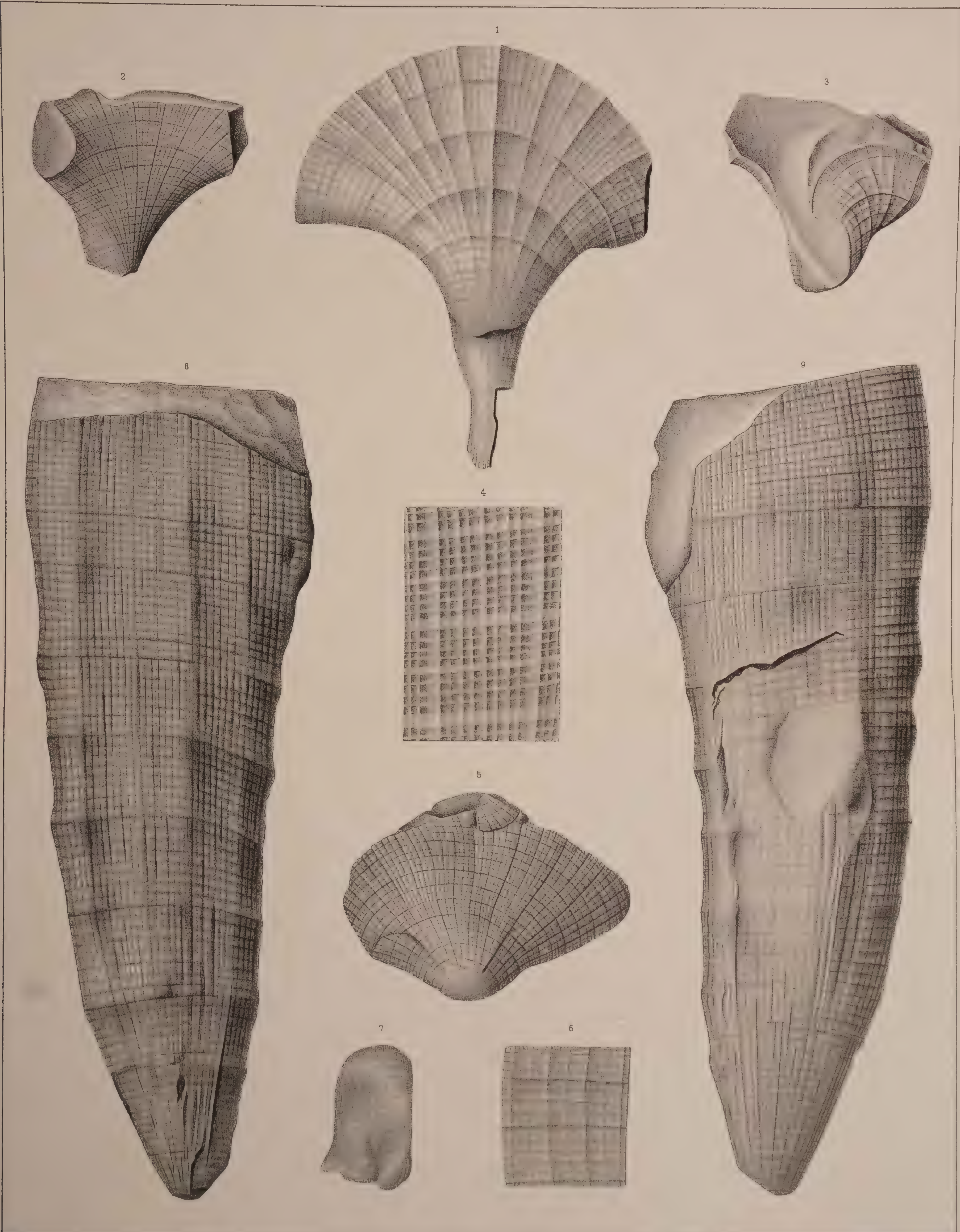
DICTYOSPONGIDÆ.

Memoirs Geological Survey of New York. Plate L.



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DICTYOSPONGIDÆ.

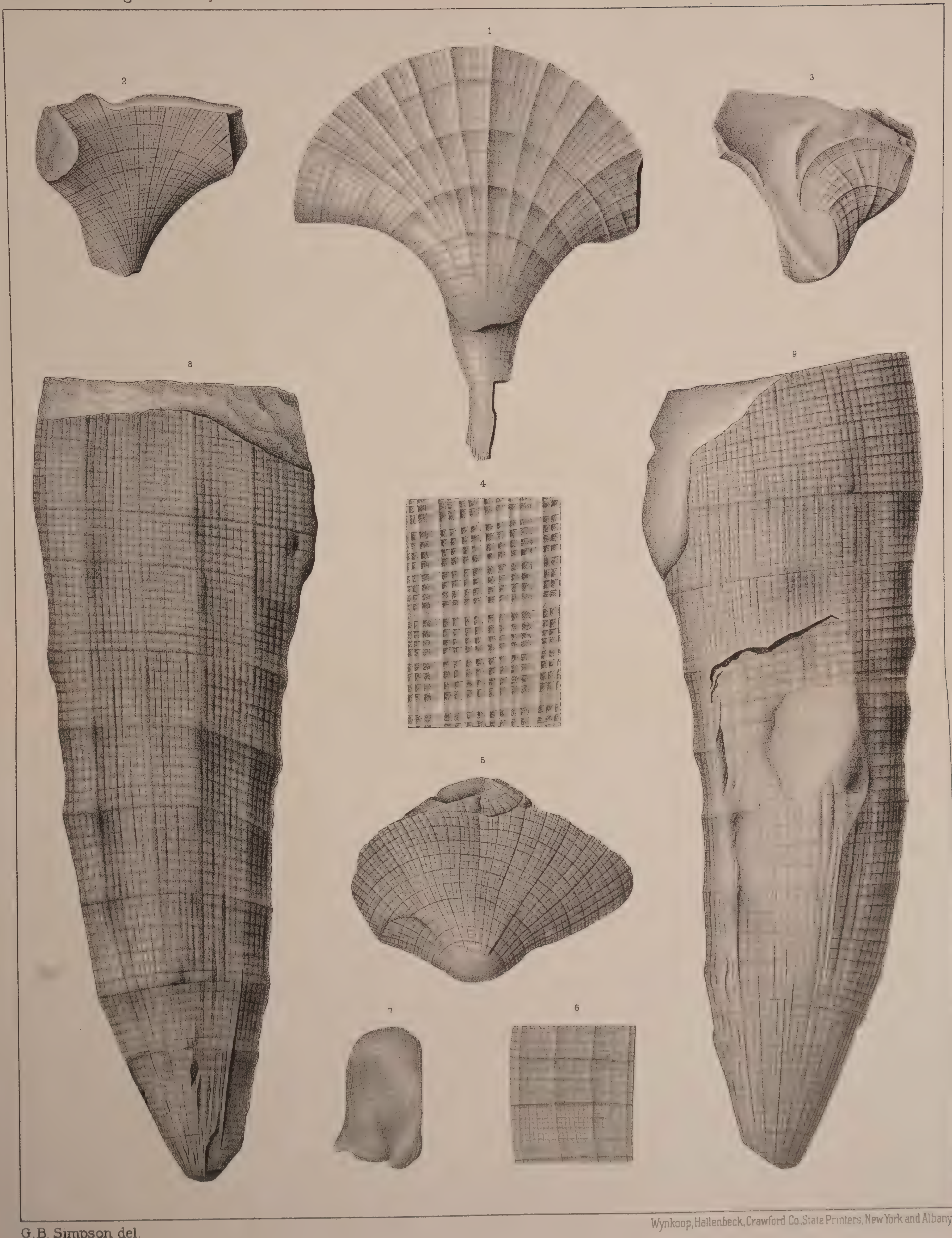

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PLATE LI.

CLEODICTYA, Hall.

Page 355.

(See Plates LXIX and LXX.)

CLEODICTYA CLAYPOLEI, sp. nov.

Page 355.

Figure 1. An incomplete example, showing the small size of the sponge, the basal row of elongate nodes and the gradual, vase-like expansion above.

Waverly group. *Akron, Ohio.*

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLVIII, XLIX, L, LII, LVI, LVII, LX, LXVIII.)

CALATHOSPONGIA CARCERALIS, sp. nov.

Page 349.

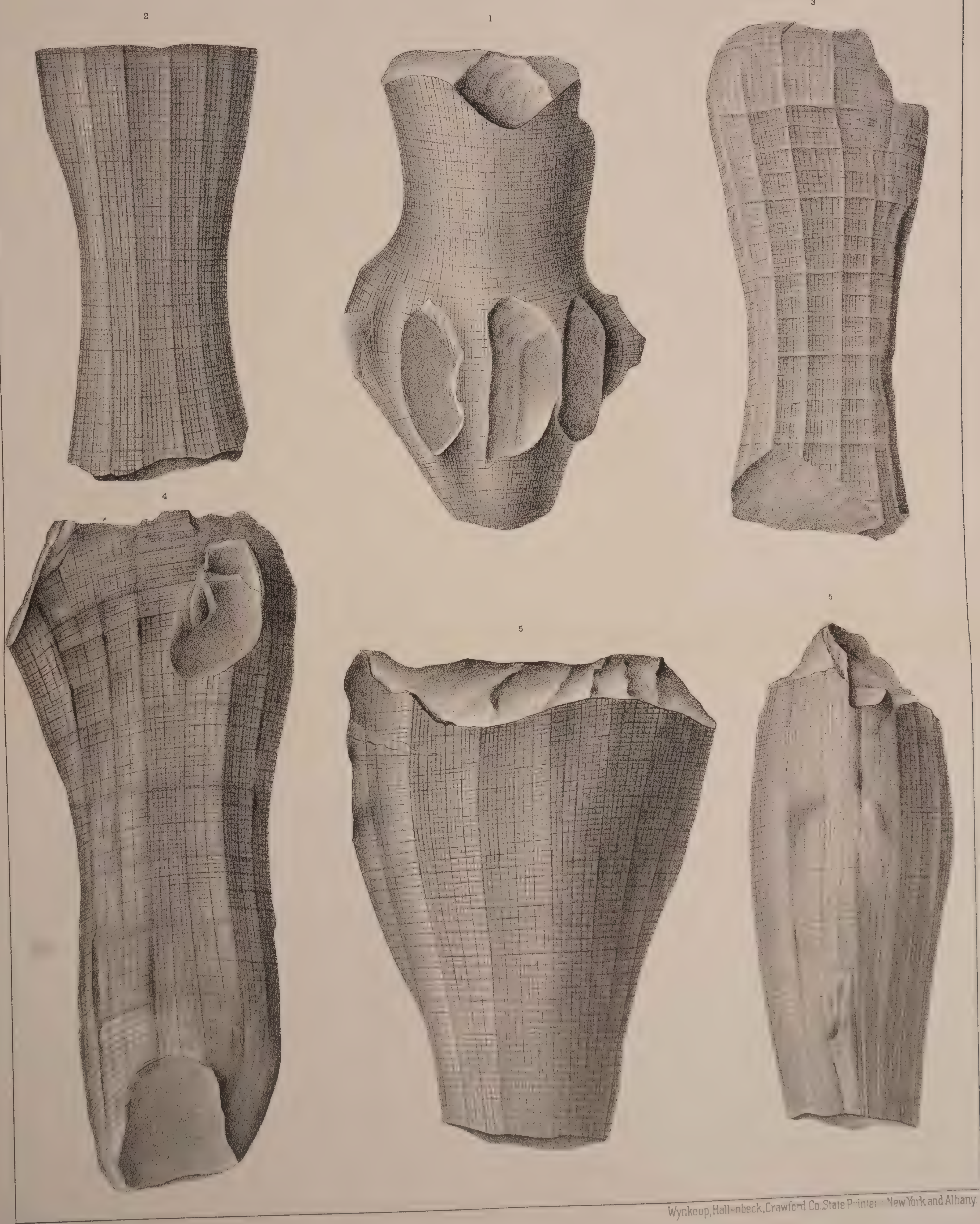
(See Plates LII and LX.)

Figures 2, 3. Opposite sides of a specimen, evidently entire, but somewhat irregular at the aperture, and nearly complete at the base. The specimen shows the strong reticulation and the prominence of the primary bands, in which respect it is unlike other species referred to the genus, though agreeing with them in its form and broad base. The apertural margin, as shown in fig. 1, is entire and regular but the growth of the sponge seems to have been abruptly stopped on this side, as, upon the opposite surface, it is continued for a considerable distance further upward. This is evidently not due to a distortion of the skeleton for the horizontal bands may be traced continuously about the surface without deviation from their plane.

Figure 4. A larger, nearly complete specimen. This is a figure which was used in the original illustration of *Dictyophyton Newberryi* (Sixteenth Annual Report of the N. Y. State Cabinet, pl. iv, fig. 3), but the surface represented shows much less distinctly than the opposite side of the specimen the coarse primary quadrules and spicular bands.

Waverly group. *Richfield, Ohio.*

DICTYOSPONGIDÆ.



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CALATHOSPONGIA TIFFANYI, sp. nov.

Page 350.

Figures 5, 6. Views of a somewhat compressed specimen showing the rate of expansion of the sponge and its obscurely prismatic surface. Waverly group. *Ohio* (*precise locality not known*).

PLATE LII.

THAMNODICTYA, Hall.

Page 352.

(See Plates L and LIII.)

THAMNODICTYA NEWBERRYI, Hall.

Page 353.

(See Plate L.)

Figure 1. The upper vase-shaped part of a large individual, the apertural portion being bent down and flattened.
Waverly group. *Richfield, Ohio.*

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLVIII, XLIX, L, LI, LVI, LVII, LX, LXVIII.)

CALATHOSPONGIA CARCERALIS, sp. nov.

Page 349.

(See Plates LI and LX.)

Figure 2. An essentially entire example with well developed prism-faces.

Figure 3. A small individual with obscure prismatic division.
Waverly group. *Richfield, Ohio.*

CALATHOSPONGIA CARLLI, sp. nov.

Page 350.

Figures 4, 5. Two views of a nearly entire but somewhat distorted specimen, showing the narrow basal part and wide apertural expansion.

Figures 6, 7. Opposite sides of a small example, essentially entire at both extremities.
Waverly group. *Near Pleasantville, Venango county, Pennsylvania.*

DICTYOSPONGIDÆ.

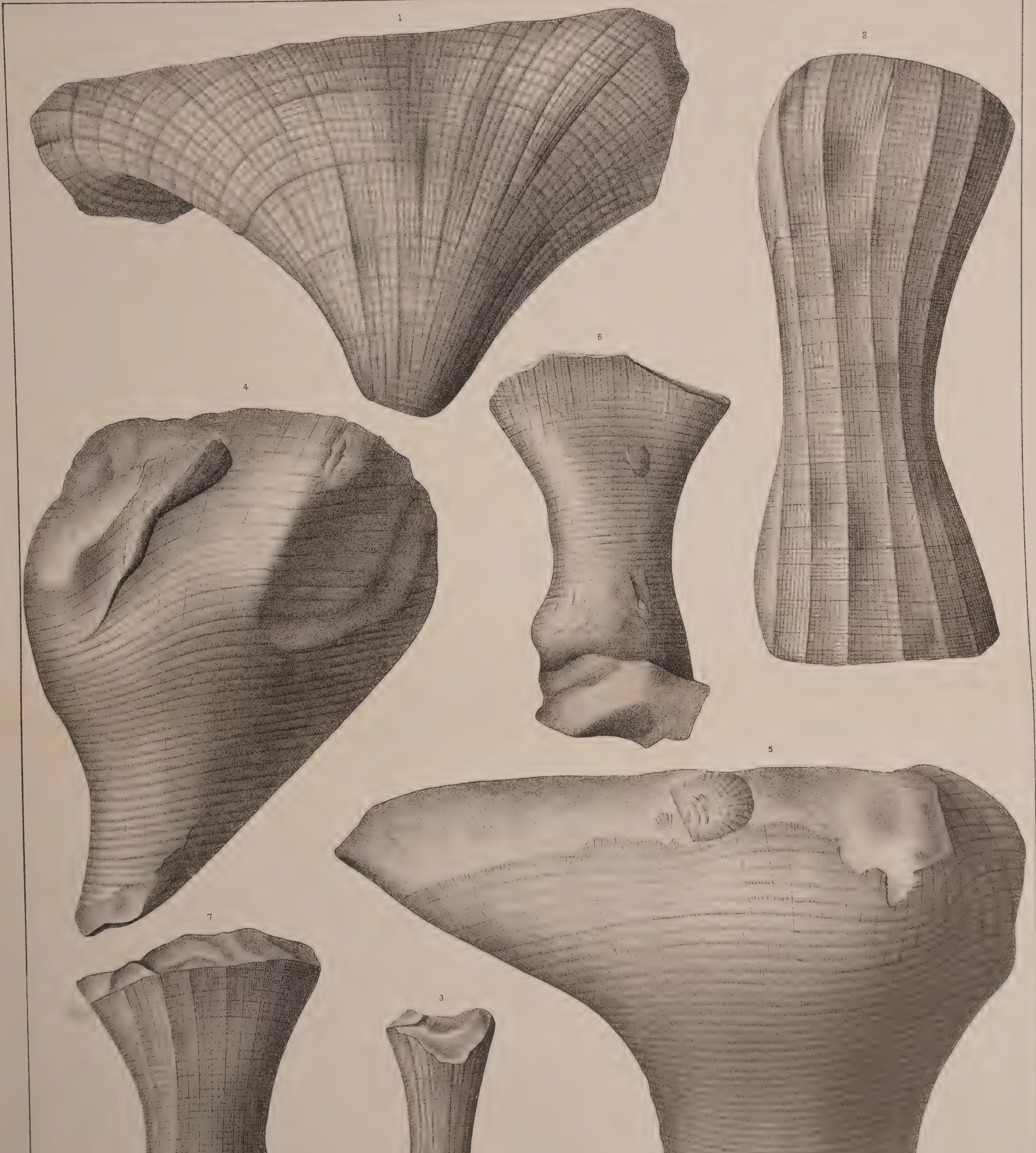

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PLATE LIII.

THAMNODICTYA, Hall.

Page 352.

(See Plates L and LII.)

THAMNODICTYA ORTONI, sp. nov.

Page 354.

Figures 1, 2. Opposite sides of a specimen which is an internal cast of the expanded apertural portion of the sponge, the smooth lower point representing the place of attachment of the pedicel. The species is characterized by the fineness of the reticulation, the peculiar curvature of the vertical bands and its large size.

Waverly group. *Moot's Run, Licking county, Ohio.*

THYSANODICTYA, gen. nov.

Page 865, part 1.

(See Plates XIX, XXIII, XXIV, XXV, XXVI, XXVII, XXXVIII, XXXIX, XL, XLII.)

THYSANODICTYA EXPANSA, Hall (sp.).

Page 346.

Figure 3. A large basal disc or diaphragm characterized by its irregularly radiating spicular bands and nodose periphery. This represents an individual of great size.

Waverly group. *Warren, Pennsylvania.*

TYLODICTYA, gen. nov.

Page 343.

TYLODICTYA (?) TENUIS, Hall (sp.).

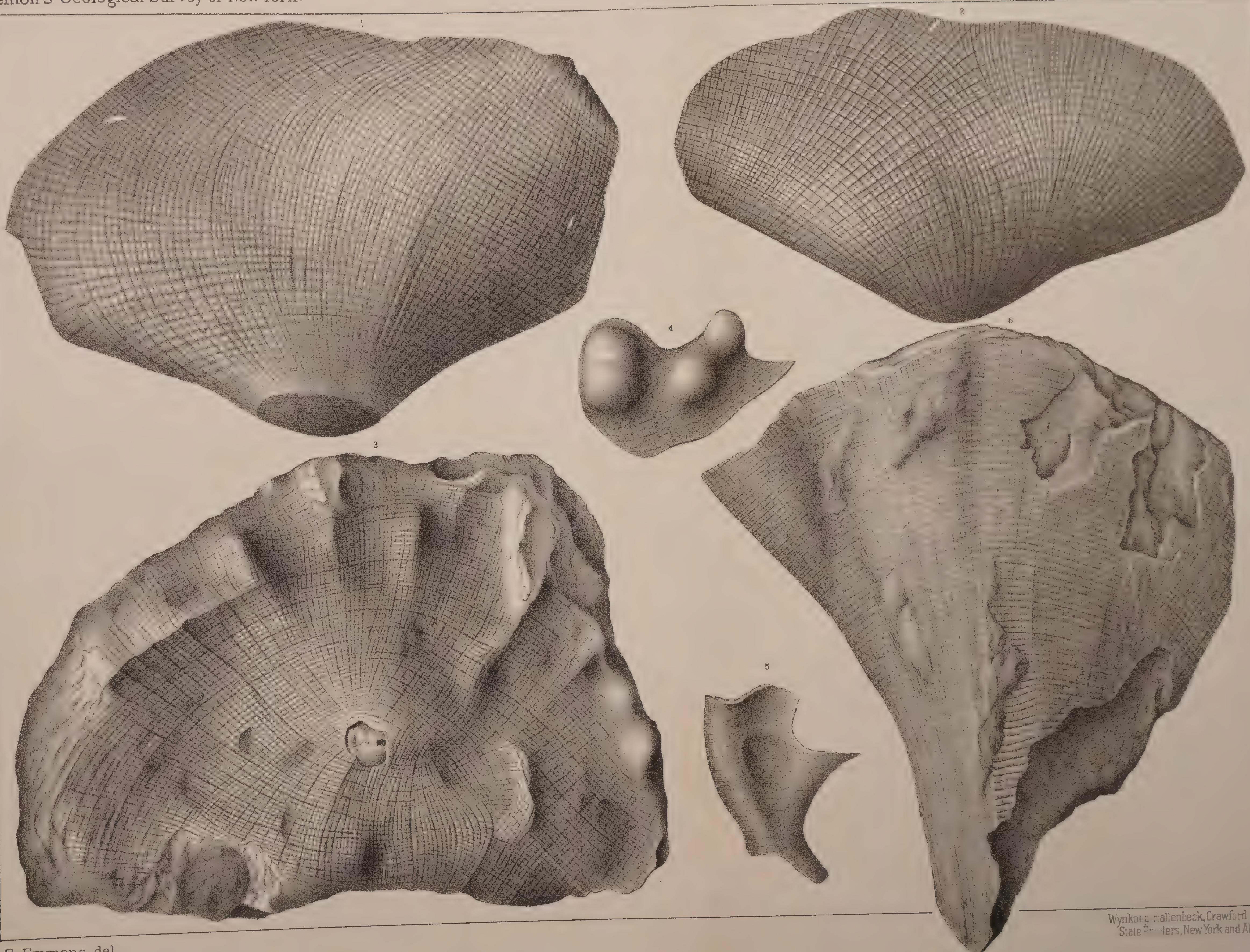
Page 344.

Figure 4. A small portion of a frond showing two double nodes, one more distinctly divided. Drawn from a cast of the original impression.

Figure 5. The original illustration of this species, showing the impression of one of the double nodes and the extremely fine reticulation of the surface, but with the specimen oriented differently than in fig. 4.

Waverly group. *Warren, Pennsylvania.*

DICTYOSPONGIDÆ.



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LYRODICTYA, Hall.

Page 362.

(See Plate LVI.)

LYRODICTYA (?) BURLINGTONENSIS, Hall (sp.).

Page 357.

Figure 6. A view of the original specimen, which is a fragment of a broadly expanded frond with strong bundles of vertical spicules, compacted at the base but diffused toward the apertural portion. The reticulation is uniformly fine.

Burlington group (Yellow sandstones). *Burlington, Iowa.*

PLATE LIV.

ACLŒODICTYA, gen. nov.

Page 369.

(See Plates LV, LX, LXI, LXVIII.)

ACLŒODICTYA ECCENTRICA, Hall (sp.).

Page 371.

Figure 1. A basal disc, somewhat compressed on one side but showing the continuity of the radial striae across the apical region, in two sets reticulating with each other.

Figure 2. A portion of a larger disc showing a tendency to the formation of elongate nodes or ridges near the periphery.

Keokuk group. *Crawfordsville, Indiana.*

(?) ECTENODICTYA, Hall.

Page 356.

(?) ECTENODICTYA IMPLEXA, Hall.

Page 356.

Figure 3. A large irregularly enfolded frond which has been much weathered. The net-work is very fine but is crossed by stronger horizontal bands like those in fig. 4, though these are much obscured in the specimen and are not represented in the drawing. Enclosed in this specimen is the original example of *Clathrospongia abacus*, figured upon Plate xlix.

Waverly group. *Warren, Pennsylvania.*

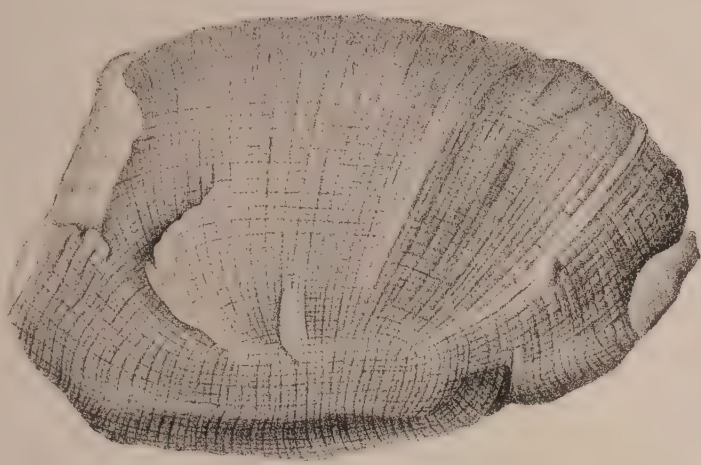
Figure 4. Another fragmentary sponge, showing the horizontal bands of the reticulum.

Waverly group. *Oil City, Pennsylvania.*

Both of these specimens have a reticulum very similar to that characterizing *Calathospongia Redfieldi* and *C. Carlli*, and it is probable that such incomplete examples are to be referred to one or the other of these species.

DICTYOSPONGIDÆ.

1



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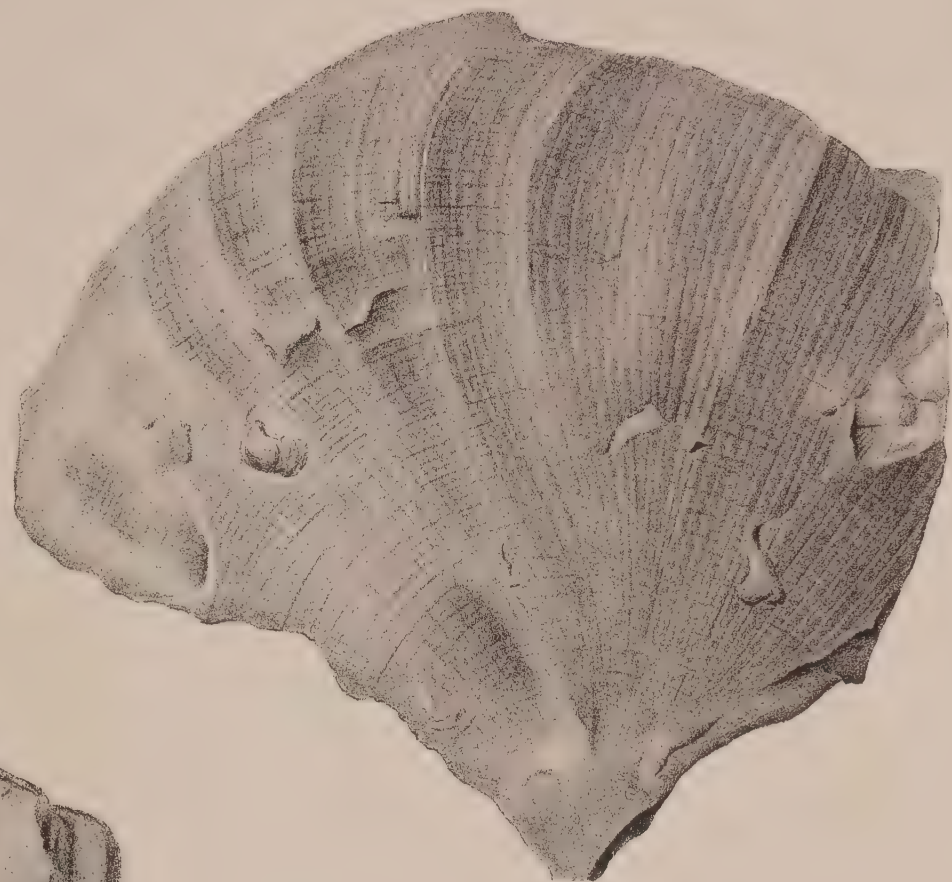

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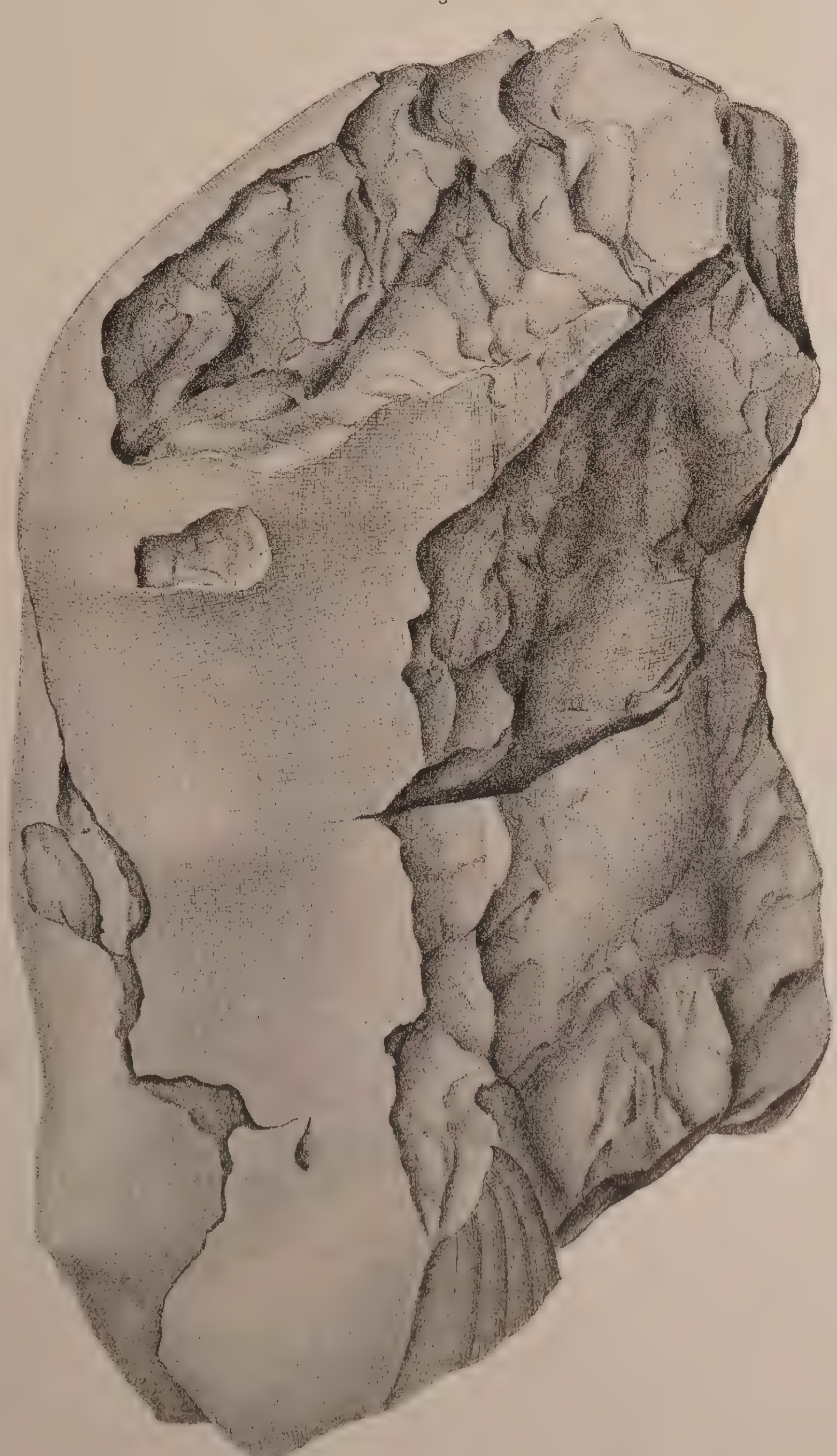

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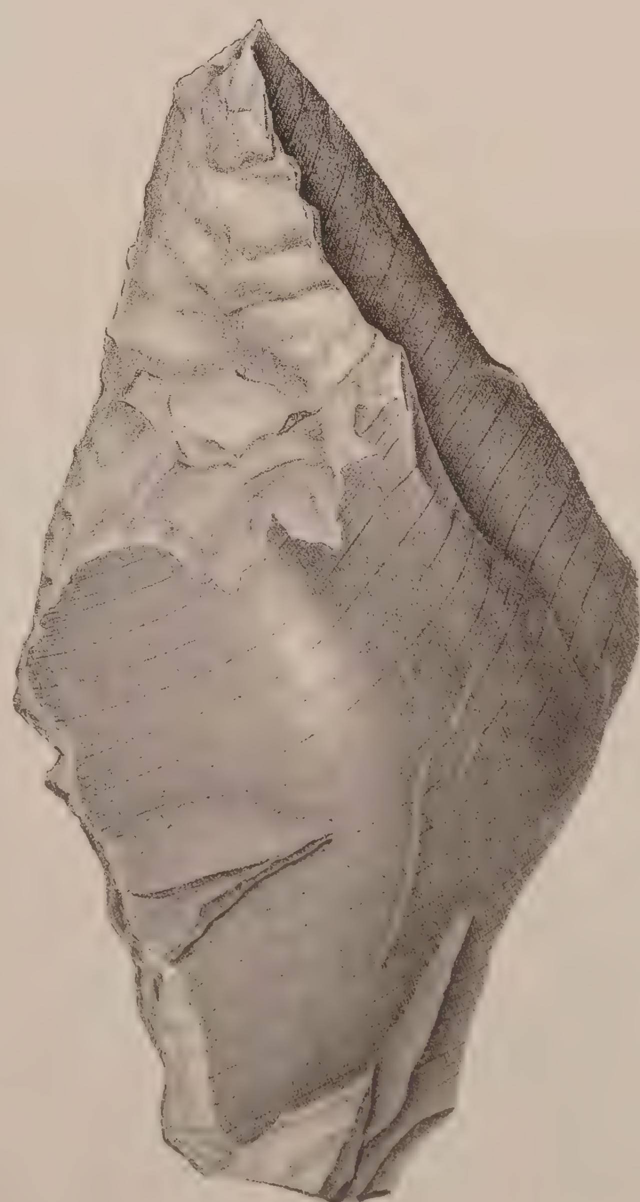

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PLATE LV.

PRISMODICTYA, gen. nov.

Page 819, part 1.

(See Plates XVII, XVIII, XIX, XX, XXI, XXVII, XXXIII, XXXIV, XXXV, XXXVI, XLI, XLII.)

PRISMODICTYA POLYHEDRA, sp. nov.

Page 360.

Figures 1, 2. Opposite sides of the original specimen.
Keokuk group. *In the shales at Crawfordsville, Indiana.*

DICTYOSPONGIA, gen. nov.

Page 812, part 1.

(See Plates XIV, XV, XVI, XXVII, XXXIII, XXXVI, XXXVIII, XLI, XLII, XLIV, XLVI, LVI, LXI.)

DICTYOSPONGIA CYLINDRICA, Whitfield (sp.).

Page 358.

Figure 3. View of the original specimen retaining the pyritized skeleton.
Keokuk group. *Crawfordsville, Indiana.*

ACLŒODICTYA, gen. nov.

Page 369.

(See Plates LIV, LX, LXI, LXVIII.)

ACLŒODICTYA MARSIPUS, sp. nov.

Page 370.

(See Plates LX, LXI, LXVIII.)

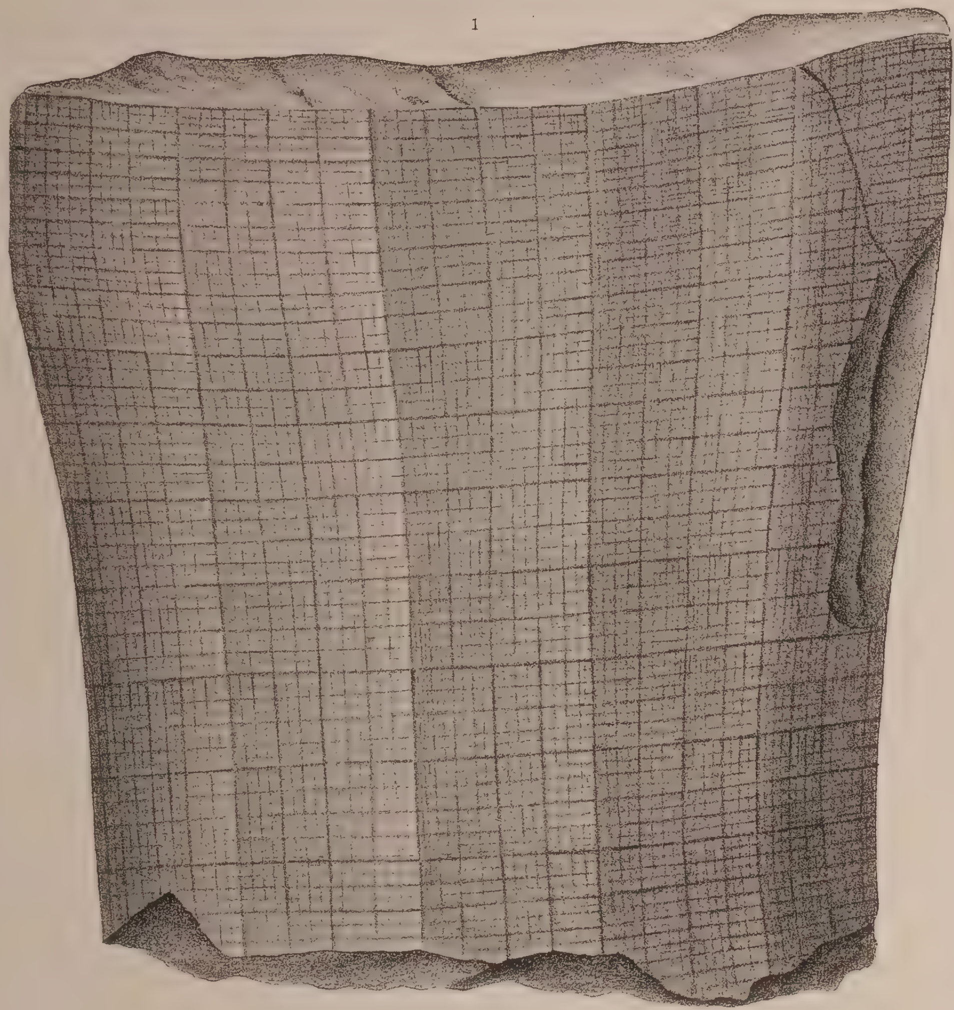
Figure 4. Portion of the specimen with pyritized skeleton; showing the extent of one of the vertical lamellae of the outer wall of the sponge.
Keokuk group. *Crawfordsville, Indiana.*

(?) LYRODICTYA, Hall.

Figure 5. Enlargement of a part of the surface of a young sponge which probably belongs to a species of this genus; showing the pyritized spicular rods of two of the vertical bundles. The quadrules bear faint traces of a fine reticulation. x3.
Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

1



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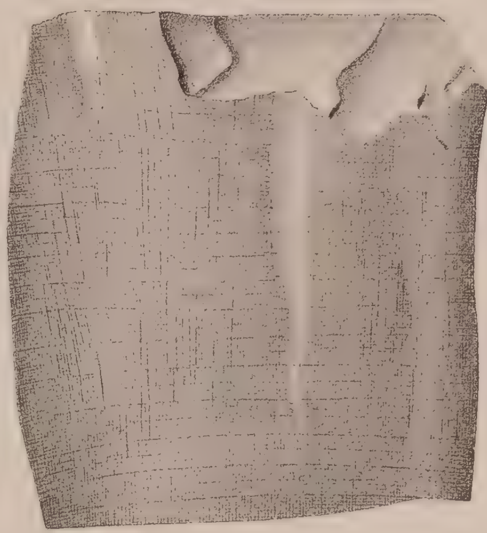

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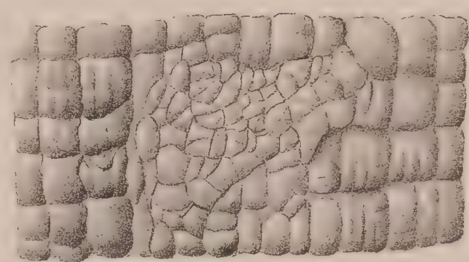

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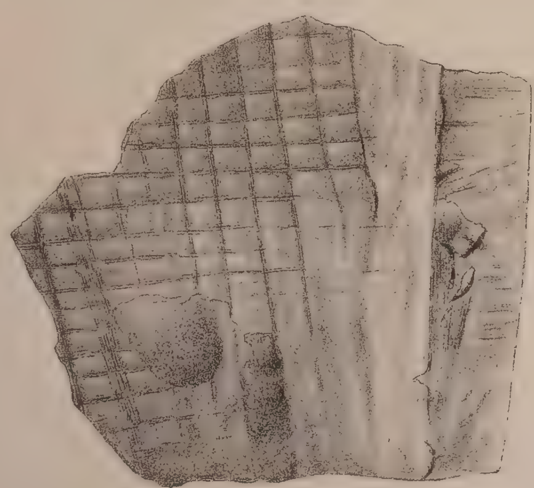

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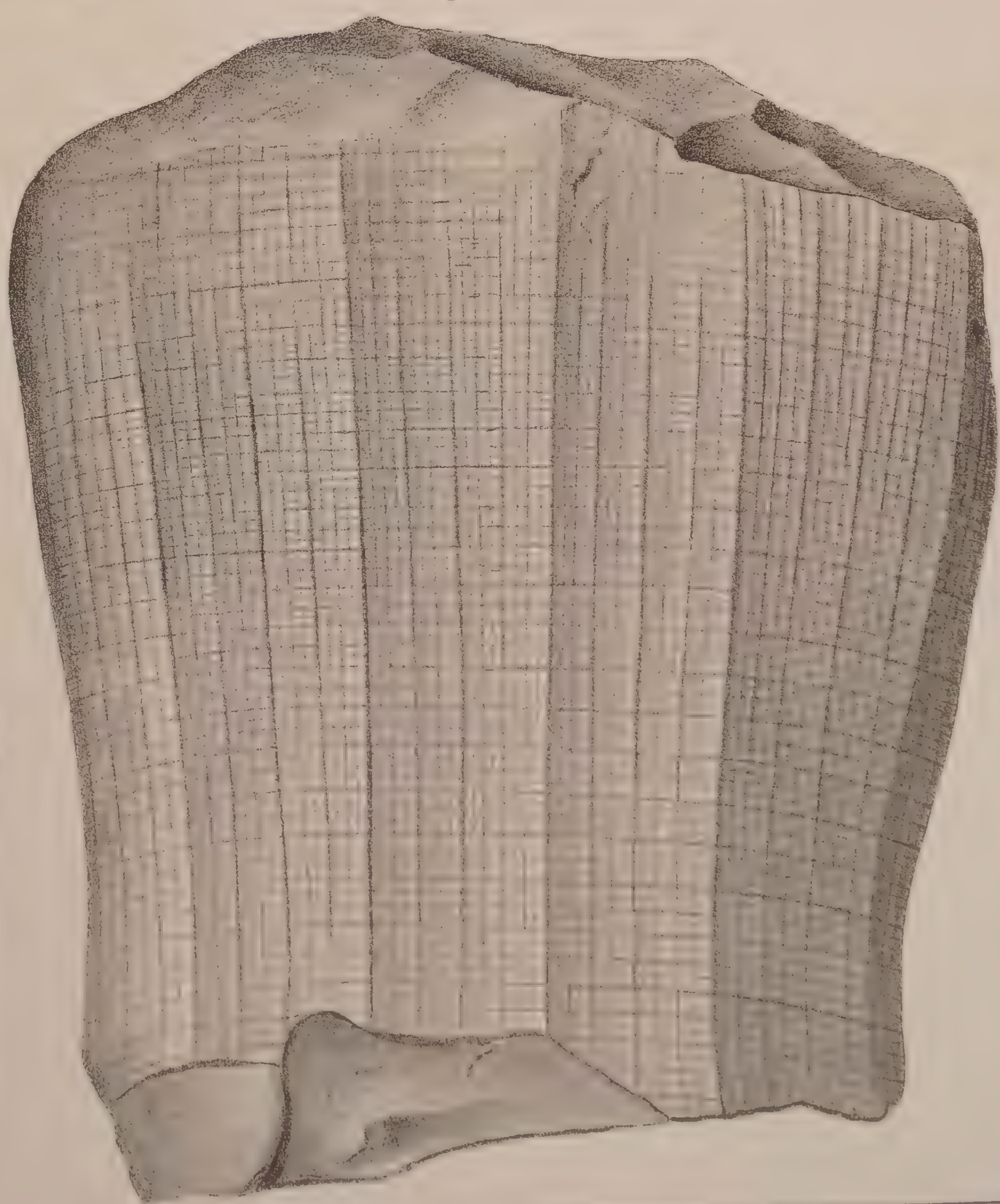

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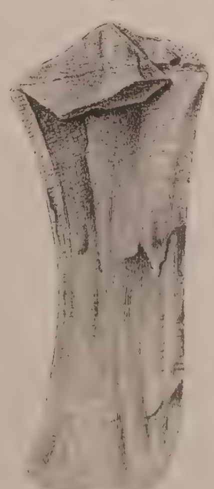

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GRIPHODICTYA, gen. nov.

Page 371.

GRIPHODICTYA EPIPHANES, sp. nov.

Page 372.

Figure 6. The specimen from which the spicules represented on page 372 were taken. This sponge has to some degree the aspect of *Phragmodictya catilliformis*, but its characteristic spicules have not been found in any other species.
Keokuk group. *Crawfordsville, Indiana.*

HYDRIODICTYA, gen. nov.

Page 817, part 1.

(See Plates IV, V, XVI, XXI.)

HYDRIODICTYA CYLIX, sp. nov.

Page 818, part 1.

(See Plates V and XVI.)

Figure 7. An enlargement of a portion of the specimen given on Plate xvi, fig. 2, showing a part of the repaired net-work of the skeleton.
Chemung group. *Deyo basin, Naples, N. Y.*

PLATE LVI.

LYRODICTYA, Hall.

Page 362.

(See Plates LIII and LV.)

LYRODICTYA ROMINGERI, Hall.

Page 362.

Figure 1. A view of the original specimen; showing the strong bundles of rod-like, vertical spicules which are increased in number upward, by intercalation, and also the finer reticulation over the broad interspaces, in which the horizontal impressions predominate.
Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIA, gen. nov.

Page 812, part 1.

(See Plates XIV, XV, XVI, XXVII, XXXIII, XXXVI, XXXVIII, XLI, XLII, XLIV, XLVI, LV, LXI.)

DICTYOSPONGIA (?) STYLINA sp. nov.

Page 359.

Figure 2. A long, slender, sponge-like body bearing horizontal and vertical striae near the top. The true character of this fossil is not fully determined but it is illustrated here on account of its resemblance to forms of DICTYOSPONGIA.
Keokuk group. *Crawfordsville, Indiana.*

PHYSOSPONGIA, Hall.

Page 379.

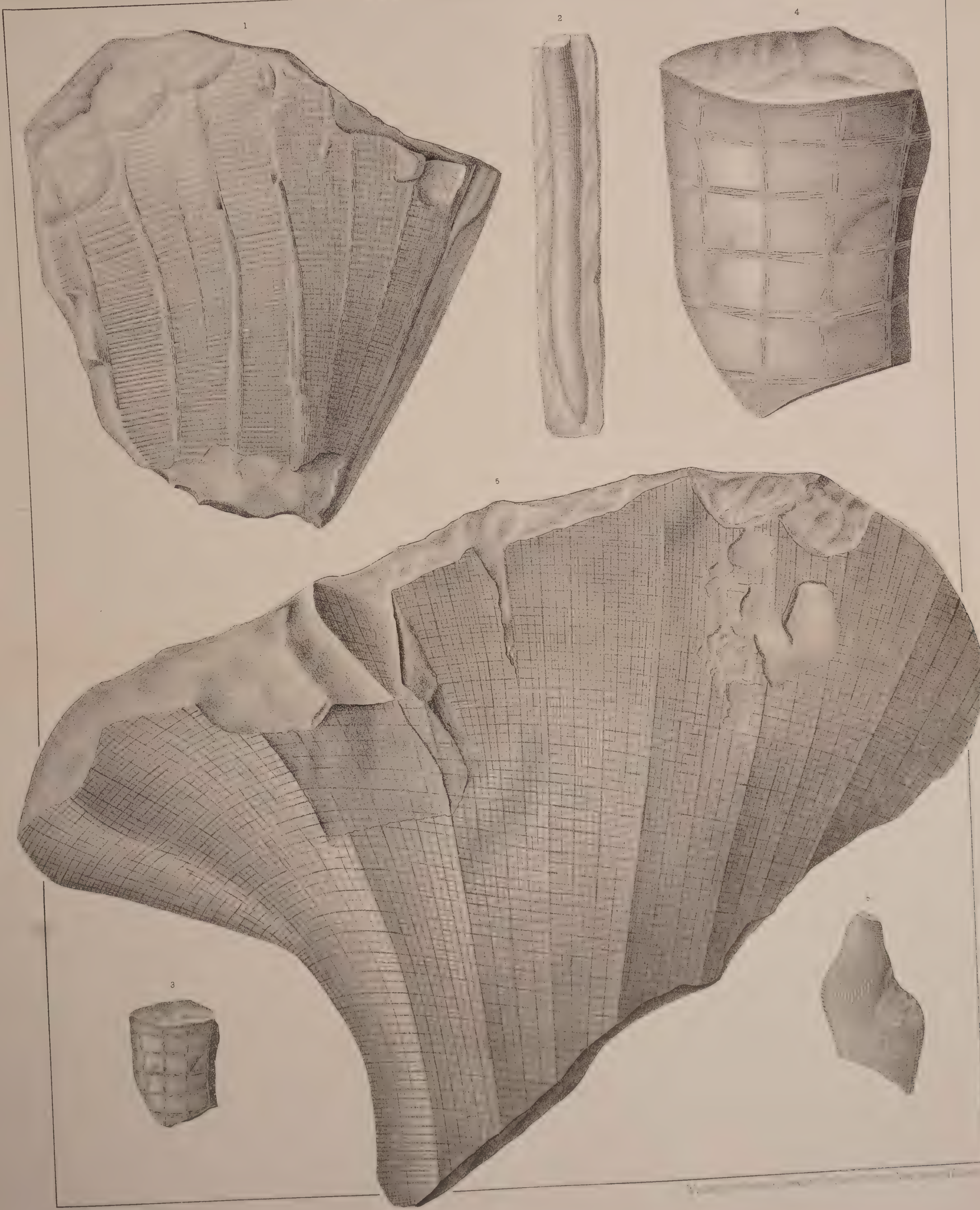
(See Plates LXI, LXII, LXIII.)

PHYSOSPONGIA, sp.?

Figure 3. A portion of the upper part of a small example in which the primary reticulating bundles of spicules are retained in a pyritized condition, while the outer portions of the skeleton are lost.

Figure 4. An enlargement of the same specimen to three diameters, showing the square and regular quadrules made by the intersecting bundles. The specimen is interesting in showing that in youth the surface of the sponge is without nodes or depressions, and it may be compared with the similar condition exhibited by the senile stage shown in figure 4, Plate lxiii.
Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.



G. B. Simpson del.

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLVIII, XLIX, L, LI, LII, LVII, LX, LXVIII.)

CALATHOSPONGIA (?) MAGNIFICA, sp. nov.

Page 374.

(See Plate LVII.)

Figure 5. The expanded apertural portion of a large sponge showing subprismatic faces.
Keokuk group. *Crawfordsville, Indiana.*

MASTODICTYA, gen nov.

Page 359.

DICTYOSPONGIA (MASTODICTYA) OSCULATA, sp. nov.

Page 359.

Figure 6. A view of the specimen described; showing the conical prolongation at the left, terminating in an osculum, the imperfect portion at the right probably representing a similar process. The reticulum is very fine, its meshes being of uniform size.
Keokuk group. *Crawfordsville, Indiana.*

PLATE LVII.

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLVIII, XLIX, L, LI, LII, LVI, LX, LXVIII.)

CALATHOSPONGIA (?) MAGNIFICA, sp. nov.

Page 374.

(See Plate LVI.)

Figure 1. The upper portion of a very large example, retaining a part of the body and enough of the apertural expansion to show its extent. Keokuk group. *Crawfordsville, Indiana.*

1

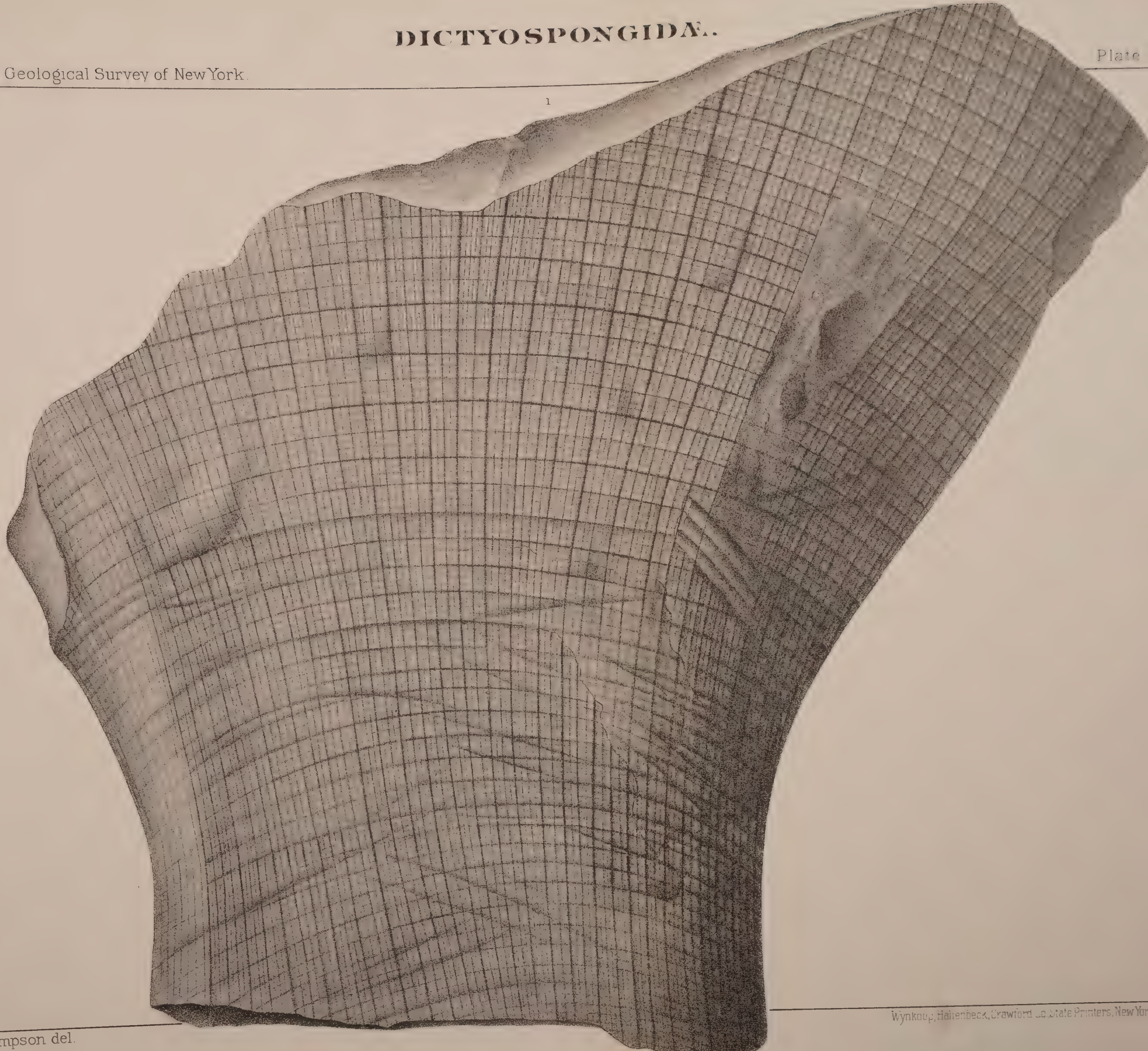


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PLATE LVIII.

LEBEDICTYA, gen. nov.

Page 361.

(See Plates LIX and LXI.)

LEBEDICTYA CRINITA, sp. nov.

Page 361.

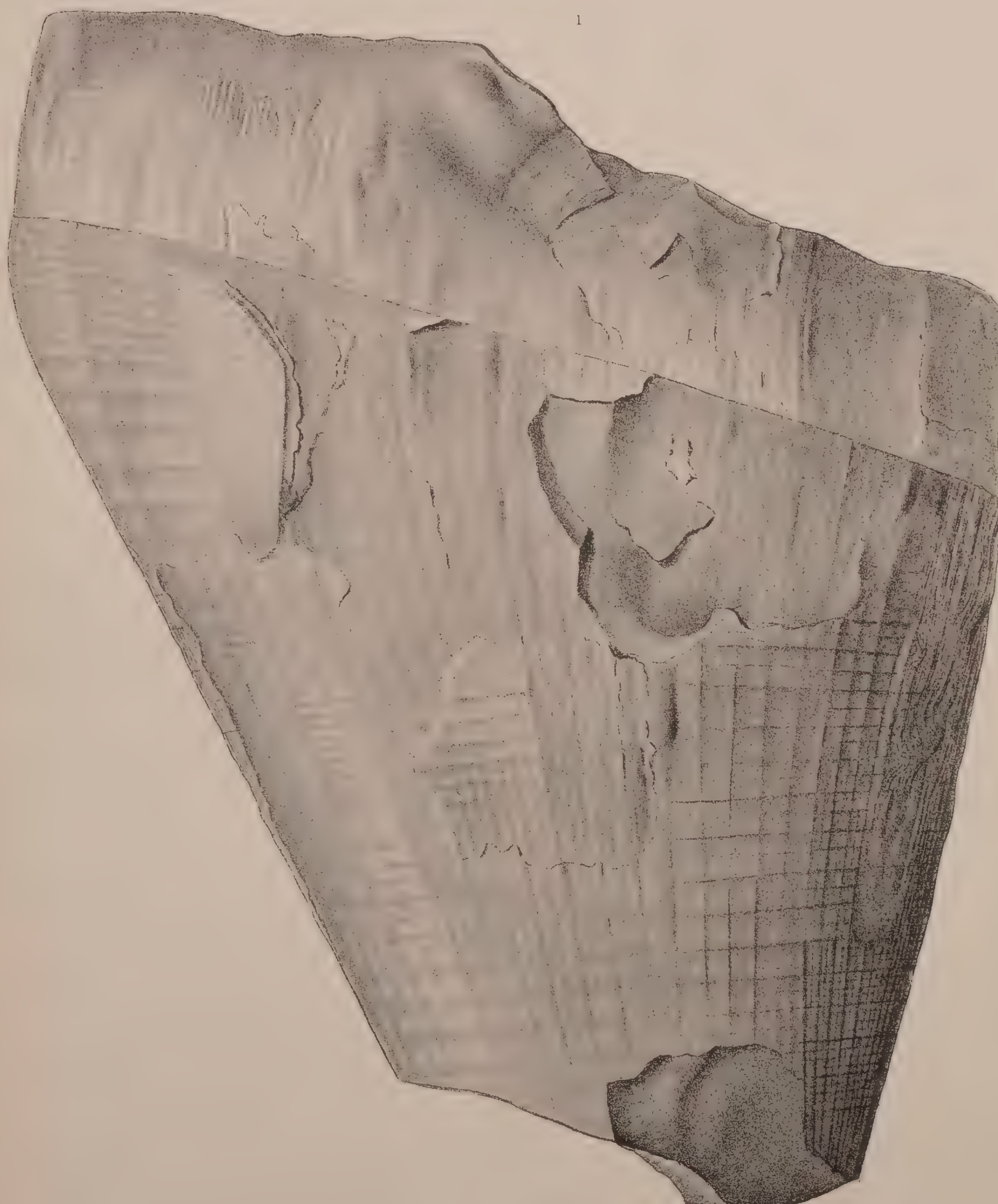
(See Plates LIX and LXI.)

Figures 1, 2. Opposite sides of a specimen, probably representing most of the sponge, retaining the aperture complete and showing its marginal fringe of long spicules. The cup has an essentially smooth, gently expanding, slightly prismatic surface; the face exposed in fig. 2 showing the finer net-work and the uneven growth of the reticulum at the margin, while the surface represented in fig. 1 shows traces of the erect outer spicular lamellae which form coarse quadrules, and at the right, where exfoliated, a large internal bundle of vertical spicules.

Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

1



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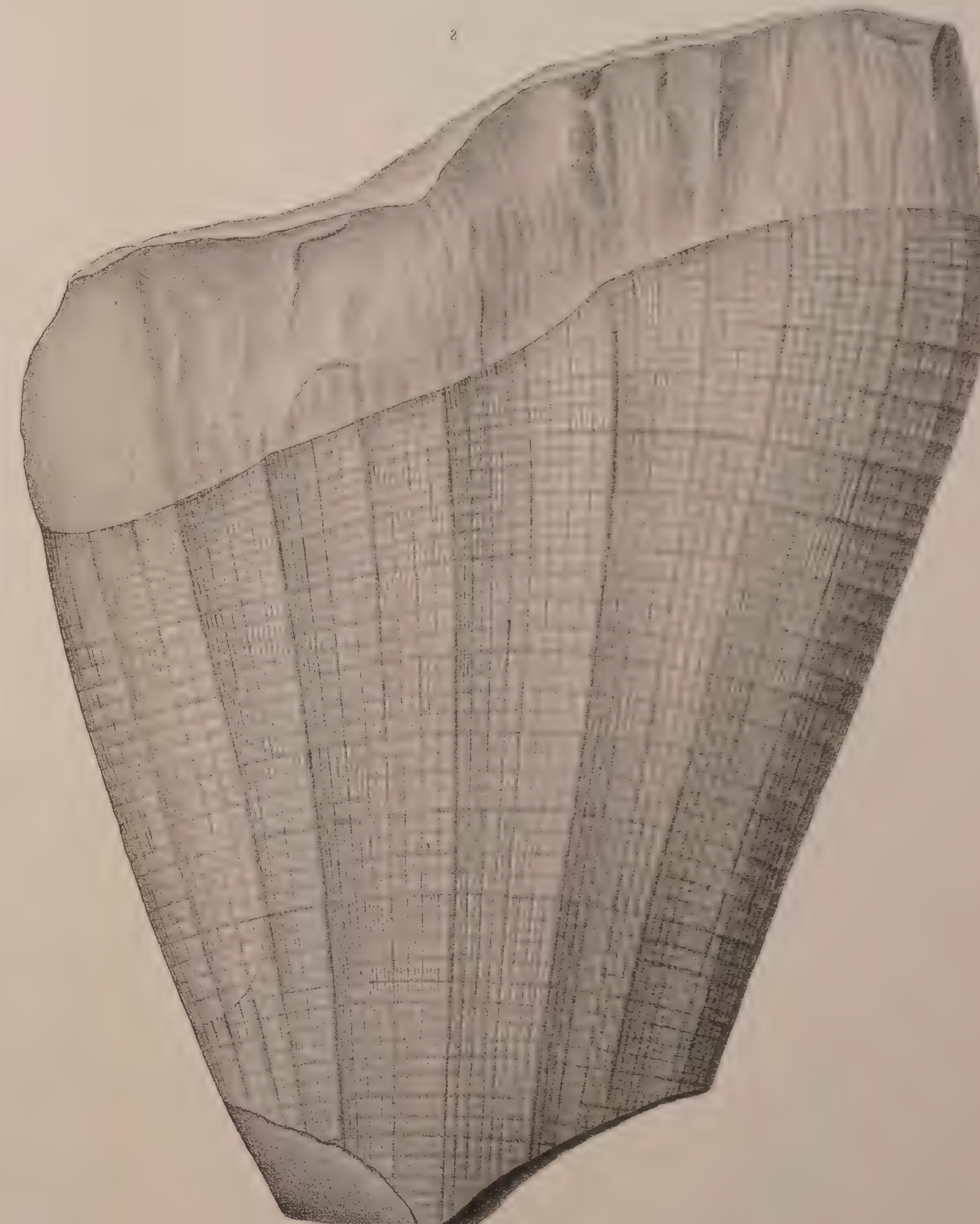

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PLATE LIX.

LEBEDICTYA, gen. nov.

Page 361.

(See Plates LVIII and LXI.)

LEBEDICTYA CRINITA, sp. nov.

Page 361.

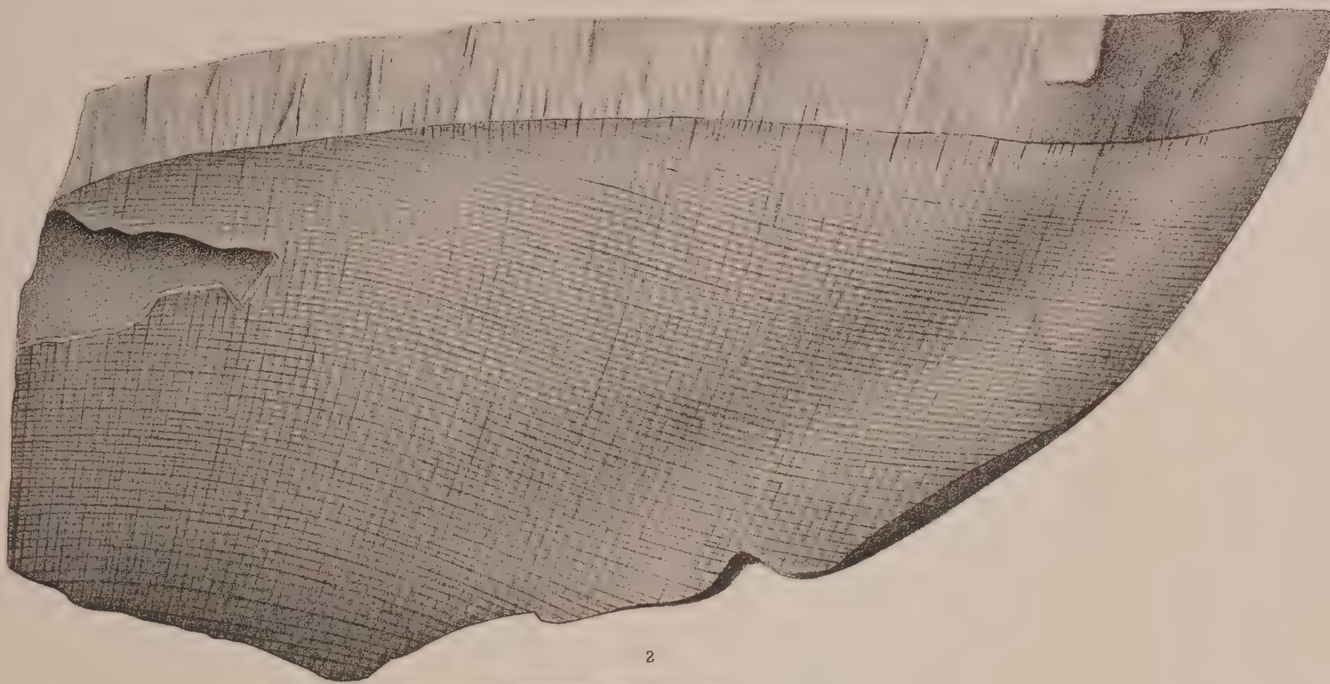
(See Plates LVIII and LXI.)

Figure 1. The apertural portion of a cup showing the marginal fringe.

Figure 2. A large, obliquely compressed cup exhibiting about one-half of the apertural margin and its spicular fringe. In both of these specimens it is seen that there is a difference in the strength of the spicules composing the fringe, the coarser seeming to lie in the line of the coarser vertical bundles of the reticulum.

Keokuk group. *Crawfordsville, Indiana.*

1



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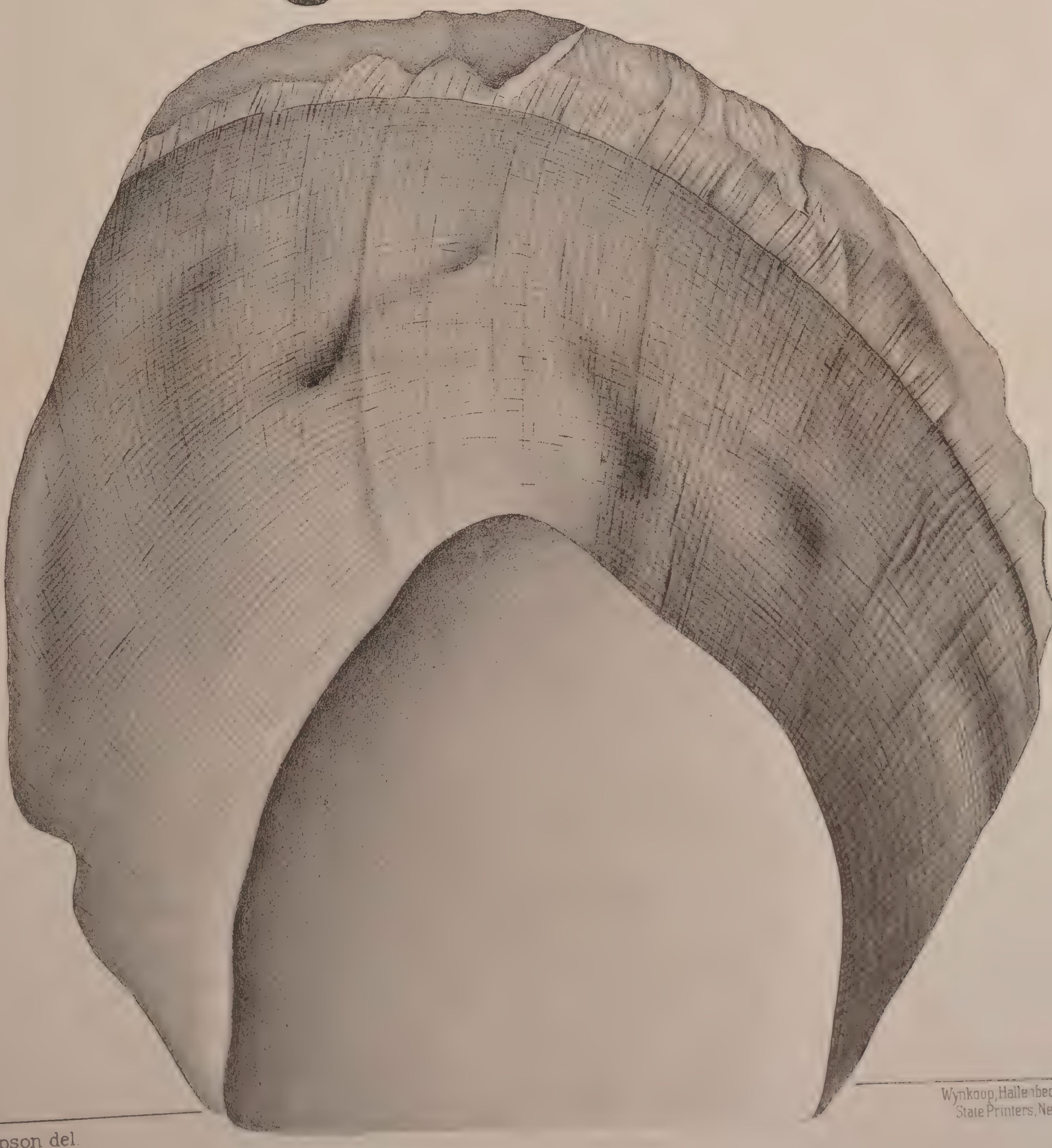

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PLATE LX.

CALATHOSPONGIA, gen. nov.

Page 347.

(See Plates XLVIII, XLIX, L, LI, LII, LVI, LVII, LXVIII.)

CALATHOSPONGIA CARCERALIS, sp. nov.

Page 349.

(See Plates LI and LII.)

Figures 1, 2. Opposite sides of a complete specimen, the side represented in fig. 1 having been somewhat abraded. This specimen shows the form of the entire sponge from aperture to base, the abrupt truncation of the latter, without evidence of basal disc, the stout body and gradual expansion toward the summit. The major quadrules of the reticulum are somewhat less conspicuous than those on the specimens from the Waverly sandstone represented on Plates li and lii, but this difference is largely due to the mode of preservation.

Keokuk group. *Crawfordsville, Indiana.*

ACLŒODICTYA, gen. nov.

Page 369.

(See Plates LIV, LV, LXI, LXVIII.)

ACLŒODICTYA MARSIPUS, sp. nov.

Page 370.

(See Plates LV, LXI, LXVIII.)

Figure 3. Lateral aspect of an incomplete specimen showing a coarsely reticulated surface and the deep basal obcone with its somewhat irregular reticulation.

Figure 4. Side view of a small and somewhat distorted specimen with a finer reticulation.

Figure 5. An entire individual, showing a very stout subcylindrical cup with a coarse, square reticulation. The basal obcone is relatively deep, forming a very obtuse angle with the walls of the sponge, and shows the absence of any peripheral fringe and also the irregular convergence and intersection of the radial bands.

Keokuk group. *Indian Creek, Indiana.*

DICTYOSPONGIDÆ.

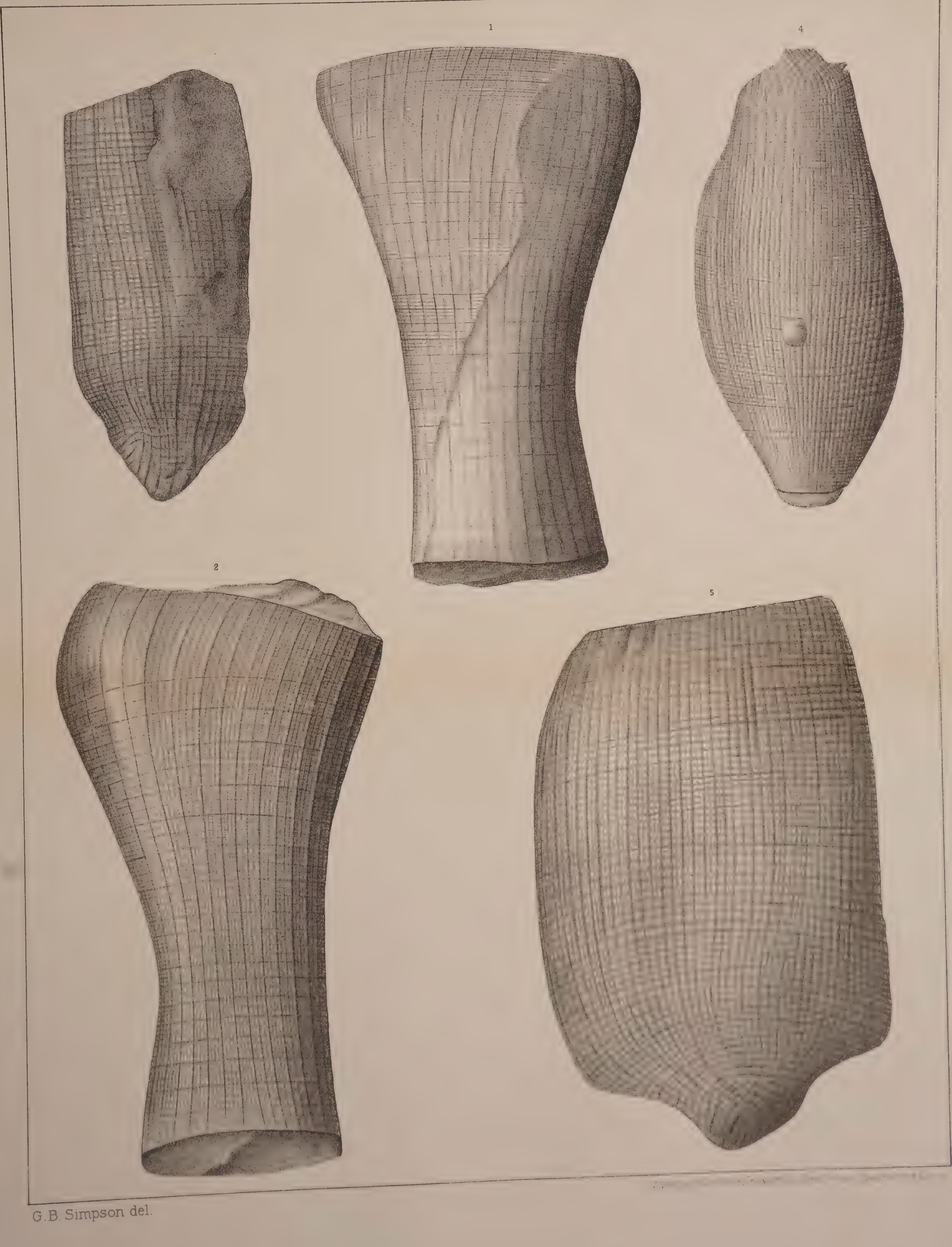

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PLATE LXI.

ACLŒODICTYA, gen. nov.

Page 379.

(See Plates LIV, LV, LX, LXVIII.)

ACLŒODICTYA MARSIPUS, sp. nov.

Page 370.

(See Plates LV, LX, LXVIII.)

Figures 1, 2. Opposite sides of the lower portion of a cup which is referred with doubt to this species.

Figure 3. A portion of the body of a cup which has retained impressions of the erect surface lamellae.

Keokuk group. *Crawfordsville, Indiana.*

PHRAGMODICTYA, Hall.

Page 364.

(See Plates LXIV, LXV, LXVI, LXVII, LXVIII.)

PHRAGMODICTYA (?) CREBRISTRIATA, Hall.

Page 368.

Figure 4. A view of the original specimen which appears to be a fragment of the apertural portion of a very finely reticulated sponge.

Keokuk group. *Crawfordsville, Indiana.*

LEBEDICTYA, gen. nov.

Page 361.

(See Plates LVIII and LIX.)

LEBEDICTYA CRINITA, sp. nov.

Page 361.

(See Plates LVIII and LIX.)

Figure 5. A portion of a small specimen showing the apertural fringe.

Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIA, gen. nov.

Page 312, part 1.

(See Plates XIV, XV, XVI, XXVII, XXXIII, XXXVI, XXXVIII, XLI, XLII, XLIV, XLVI, LV, LVI.)

DICTYOSPONGIA CYLINDRICA, Whitfield (sp.).

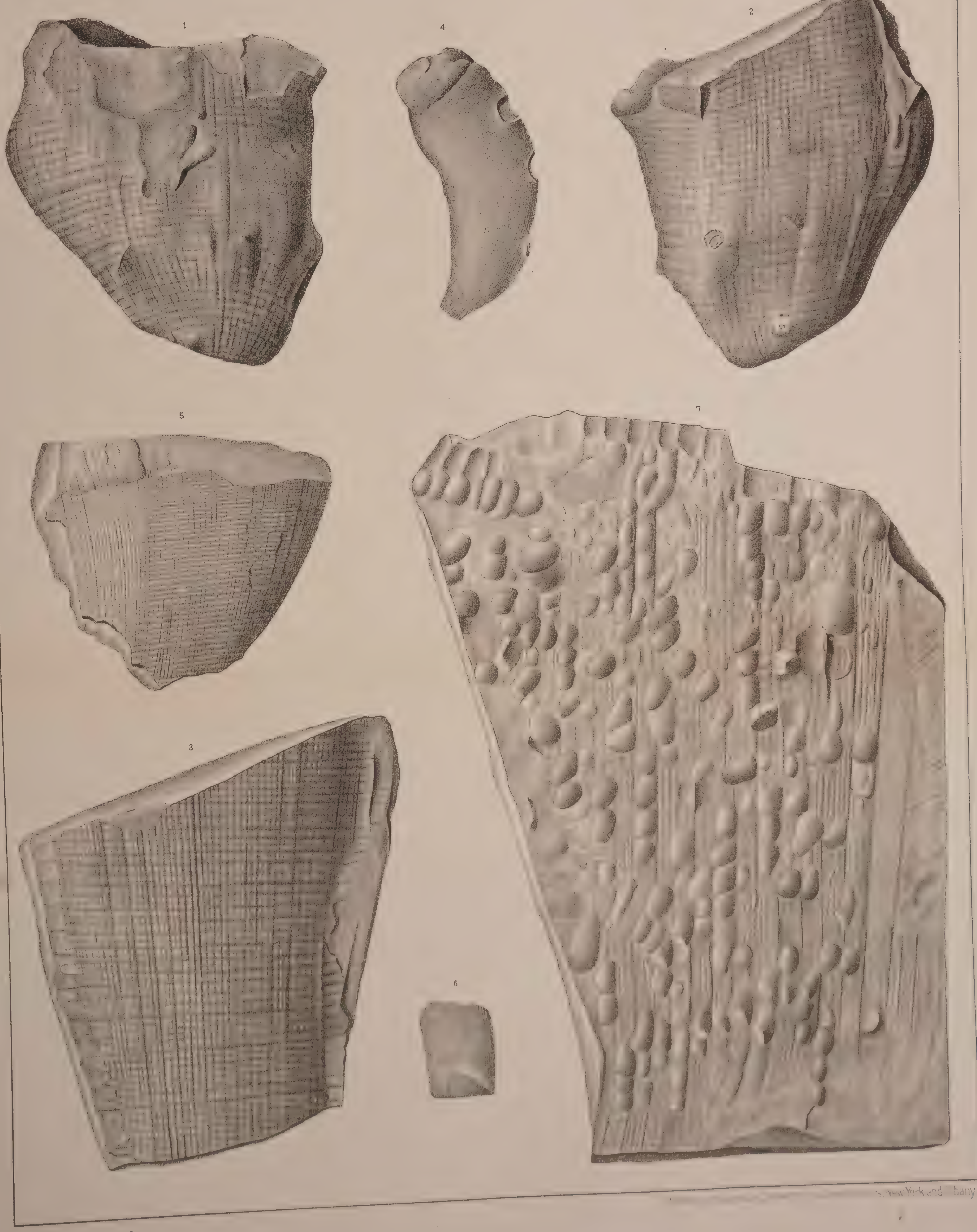
Page 358.

(See Plate LV.)

Figure 6. A fragment of a small example with pyritized spicules.

Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.



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PHYSOSPONGIA, Hall.

Page 379.

(See Plates LVI, LXII and LXIII.)

Physospongia multibursaria, sp. nov.

Page 388.

Figure 7. A portion of a frond which is a flat, undefined expansion showing a finely reticulate surface. The vertical areas lying between the principal spicular bands are more or less completely covered by pendulous, overlapping nodes in the form of internal casts without much evidence of reticulation. No other example of this species has been observed.

Keokuk group. *Crawfordsville, Indiana.*

PLATE LXII.

PHYSOSPONGIA, Hall.

Page 379.

(See Plates LVI, LXI and LXIII.)

PHYSOSPONGIA DAWSONI, Whitfield (sp.).

Page 381.

Figure 1. A portion of a slender cup showing the difference in size of the primary and secondary vertical bundles, the alternation of the nodes and concavities and the projection of a few spicular tufts at the lateral margins.

Figure 2. A nearly entire specimen of average size, abnormal in having one of the primary vertical strands of no larger size than those of the secondary series. The rapid multiplication of the quadrules is observable near the summit of the specimen. Some of the nodes are presented in profile at the sides of the specimen.

Figure 3. The lateral portion of an individual which shows in the matrix the long spicular tufts extending from the intersections of the vertical and horizontal bands.

Figure 4. The median portion of a somewhat worn specimen showing the alternating vertical strands, nodes and concavities.

Figure 5. A very regularly developed, nearly entire cup which retains the fine spicular markings of the quadrules, shows the form of some of the nodes in profile and two projecting spicular tufts.

Figure 6. A specimen which has been somewhat obliquely compressed shows the broad vertical primary spicular bands and the profile of the nodes and spicular tufts.

Figure 7. A larger example, showing an unusual development of the nodes, and the rapid increase of nodes and concavities toward the aperture, by horizontal division.

Figure 8. An enlargement of the lateral portion of a frond showing the spicular tufts arising at the intersection of the vertical and horizontal bundles. The specimen also shows, as a discoloration of the matrix, an erect lamellar film connecting the spicular tufts. This has not been observed on other examples. x3.

DICTYOSPONGIDÆ.

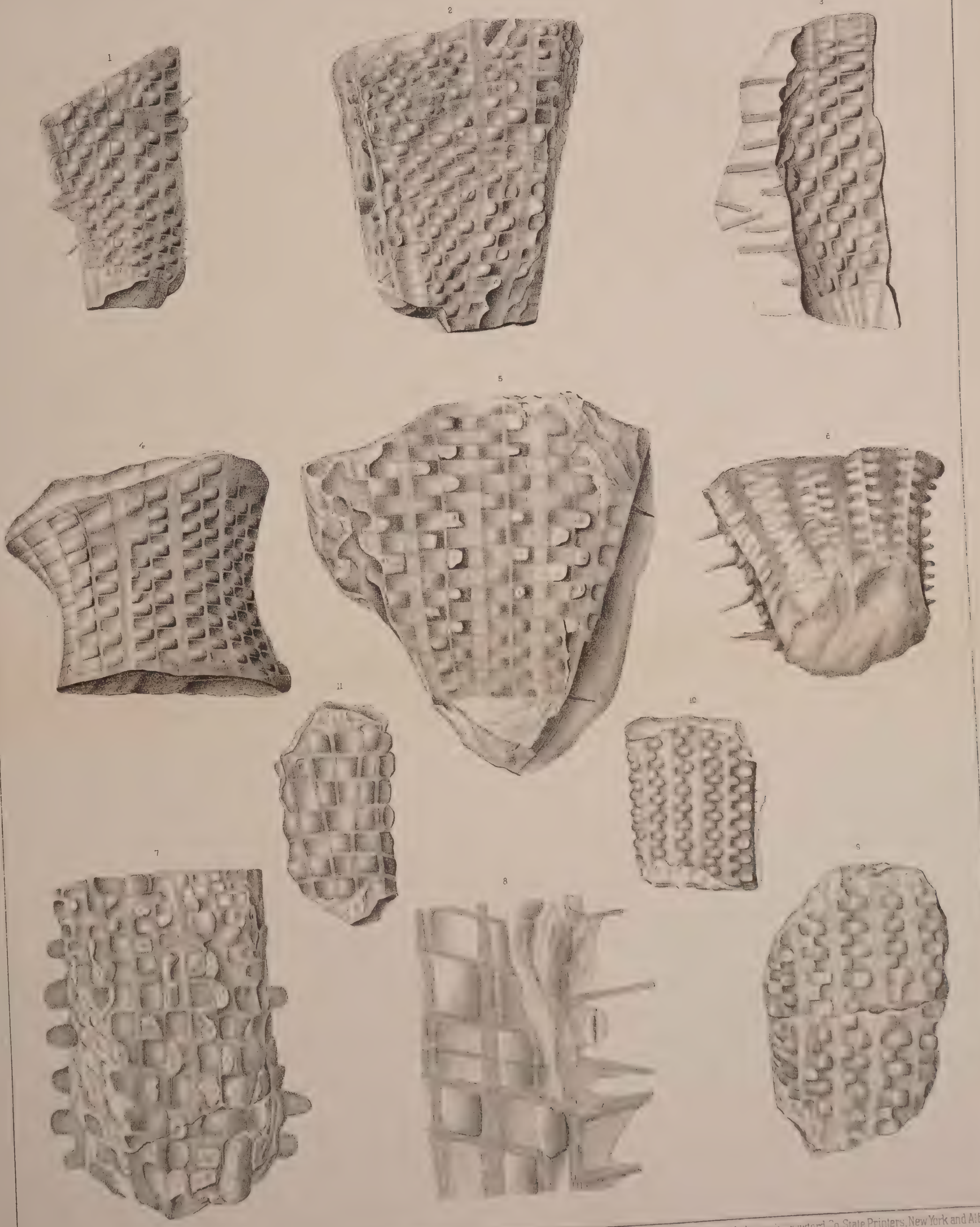

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Figure 9. An incomplete example of medium size in which the primary vertical bands are broad and the secondary bands exceedingly narrow.

Figure 10. A specimen of small size; showing the regularly alternating arrangement of the nodes.

Keokuk group. *Crawfordsville, Indiana.*

PHYSOSPONGIA ALTERNATA, Hall.

Page 387.

Figure 11. A view of the original specimen; showing the narrow, subcylindrical form with large quadrules and subequal vertical strands. In the latter there is some difference in size although not clearly shown on the somewhat abraded surface here represented.

Keokuk group. *Crawfordsville, Indiana.*

PLATE LXIII.

PHYSOSPONGIA, Hall.

Page 379.

(See Plates LVI, LXI and LXII.)

PHYSOSPONGIA COLLETTI, Hall.

Page 385.

Figure 1. A nearly entire specimen of rather small size showing the usual aspect of the species. The nodes have undoubtedly been somewhat flattened, and the secondary vertical spicular bundles are represented as rather too broad.

Figure 2. An enlargement of a portion of the surface in the same specimen, showing two nodes and their corresponding concavities, each pair being separated by a major vertical spicular band. The surface of the quadrules shows indications of a finer reticulation.

Figure 3. A fragment of a large, somewhat irregular example, showing the obsolescence of the nodes near the aperture.

Figure 4. An enlargement of the surface in the smooth apertural region of the foregoing specimen, showing the diminution in the size of the spicular bundles. x2.

Figure 5. The apertural major portion of a sponge; showing the diffusion of the vertical spicular bands of the first order, and the multiplication of the quadrules by increase in the number of both horizontal and vertical bundles. At the aperture all nodes and depressions have become obsolete.

Figure 6. A portion of the same specimen redrawn to show more distinctly the multiplication of the nodes by horizontal and vertical division. Natural size.

Figure 7. A portion of a very large specimen, natural size, in which the fine reticulation of the quadrules is distinctly retained.

Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

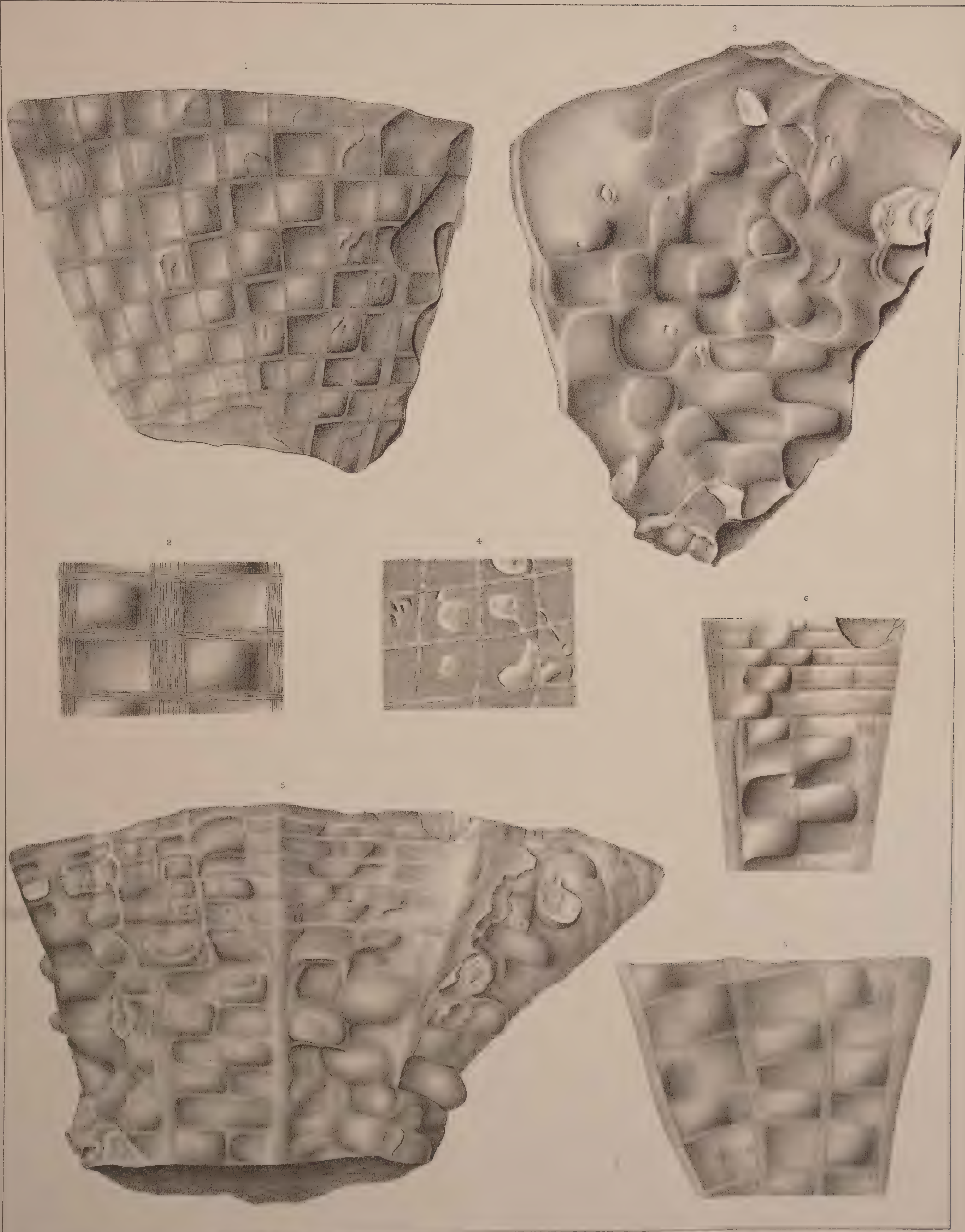

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PLATE LXIV.

PHRAGMODICTYA, Hall.

Page 364.

(See Plates LXV, LXVI, LXVII, LXVIII.)

PHRAGMODICTYA CATILLIFORMIS, Whitfield (sp.).

Page 365.

(See Plates LXV, LXVI, LXVII, LXVIII)

Figure 1. A small specimen which has been compressed vertically, disturbing the form of the cup but showing the transverse basal plate.

Figure 2. A view of the basal surface of the same specimen; showing the radiating spicular bands.

Figure 3. The basal extremity of a larger example to which the peripheral frill or periloph is attached. This specimen shows the ridged and crenulated surface of the frill, the eccentric apex of the base, and retains a part of the vertical portion of the sponge though in a compressed condition.

Figure 4. An incomplete specimen, showing the approximate outline of the entire sponge. This example has the surface ridges unusually strong and regular and some of them are evidently continued on to the periloph. The edge of the basal plate is very sharply defined.

Figure 5. An imperfect but very large example, exposing the basal area, a portion of the broad periloph and the vertical cup in a compressed condition. The convergence of the radial spicular striae of the base is very clearly defined. This is the original specimen of the species. Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

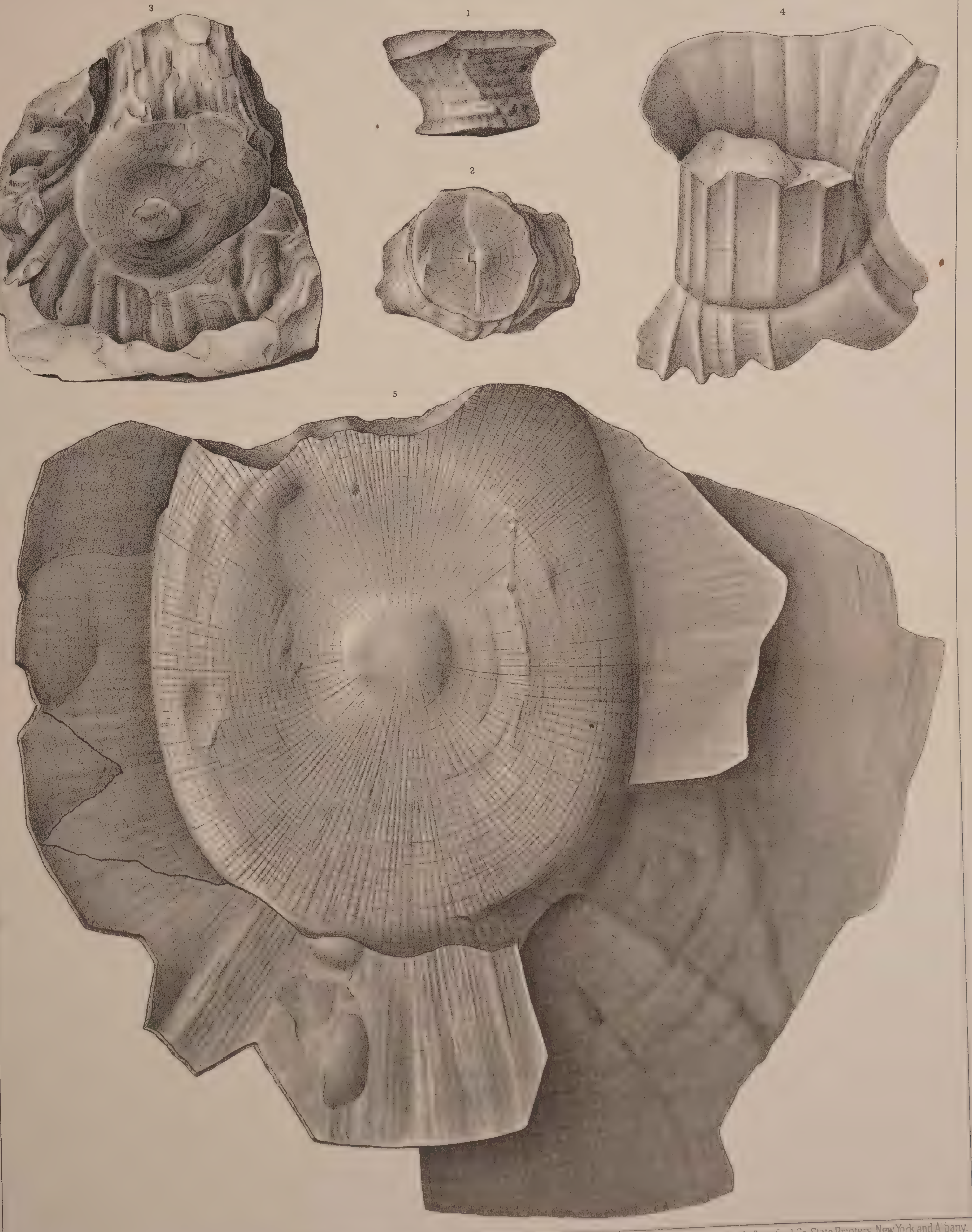

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PLATE LXV.

PHRAGMODICTYA, Hall.

Page 364.

(See Plates LXIV, LXVI, LXVII, LXVIII.)

PHRAGMODICTYA CATILLIFORMIS, Whitfield (sp.).

Page 365.

(See Plates LXIV, LXVI, LXVII, LXVIII.)

Figure 1. The lower side of a large basal disc with the entire periloph retained; showing the fine radial spicular striations of the former and the ridged surface and somewhat irregular margin of the latter.

Figure 2. A natural half section of a basal disc with a highly elliptical form, undoubtedly due to lateral compression.

Keokuk group. *Crawfordsville, Indiana.*

PHRAGMODICTYA PATELLIFORMIS, Hall.

Page 368.

Figure 3. The lower surface of a large basal disc with a highly eccentric apex.

Keokuk group. *From the sandy calcareous layers overlying the calcareous shales, at Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

1

2

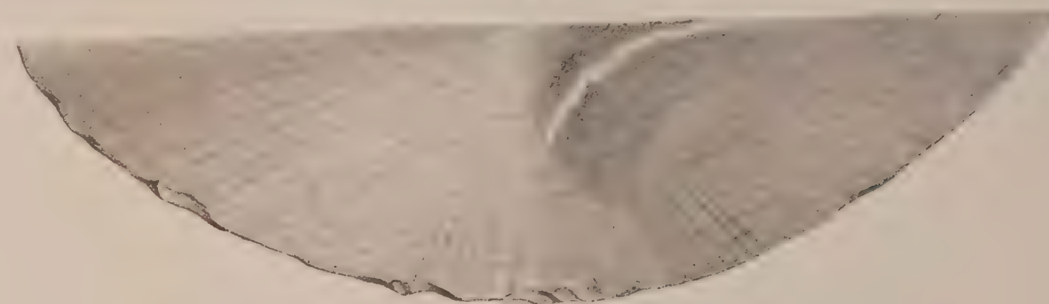

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PLATE LXVI.

PHRAGMODICTYA, Hall.

Page 364.

(See Plates LXIV, LXV, LXVII, LXVIII.)

PHRAGMODICTYA CATILLIFORMIS, Whitfield (sp.).

Page 365.

(See Plates LXIV, LXV, LXVII, LXVIII.)

Figure 1. A small basal disc with sharp and fine radial striae.

Figure 2. A portion of a large specimen; showing the extremely fine reticulum, the discontinuous vertical ridges and the convexity of the basal disc.

Figure 3. A portion of a very broad periloph, showing the fine net-work, the ridged surface and the irregular free margin.

Figure 4. A part of the reticulum about the apertural margin; showing scattered nodes and nodiform ridges, and a smooth surface at the margin itself.

Figure 5. A small, nearly entire individual, with broadly expanded aperture. This specimen retains the probable outline of the species, except for the obliquity of the lower part of the cup.

Figure 6. The lower portion of an internal cast, showing the convexity of the basal plate and the regular convergence of the vertical striae.

Figure 7. A small specimen, entire from the basal disc to the aperture; showing the expanding form of the cup.

Figure 8. A specimen of moderately large size, entire except about the aperture, the parts being detached at the basal disc, showing the form and depth of the latter and the length and character of the periloph.

Figure 9. The same specimen with the parts brought together into their normal condition.

Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

Memoirs Geological Survey of New York.

Plate LXVI.

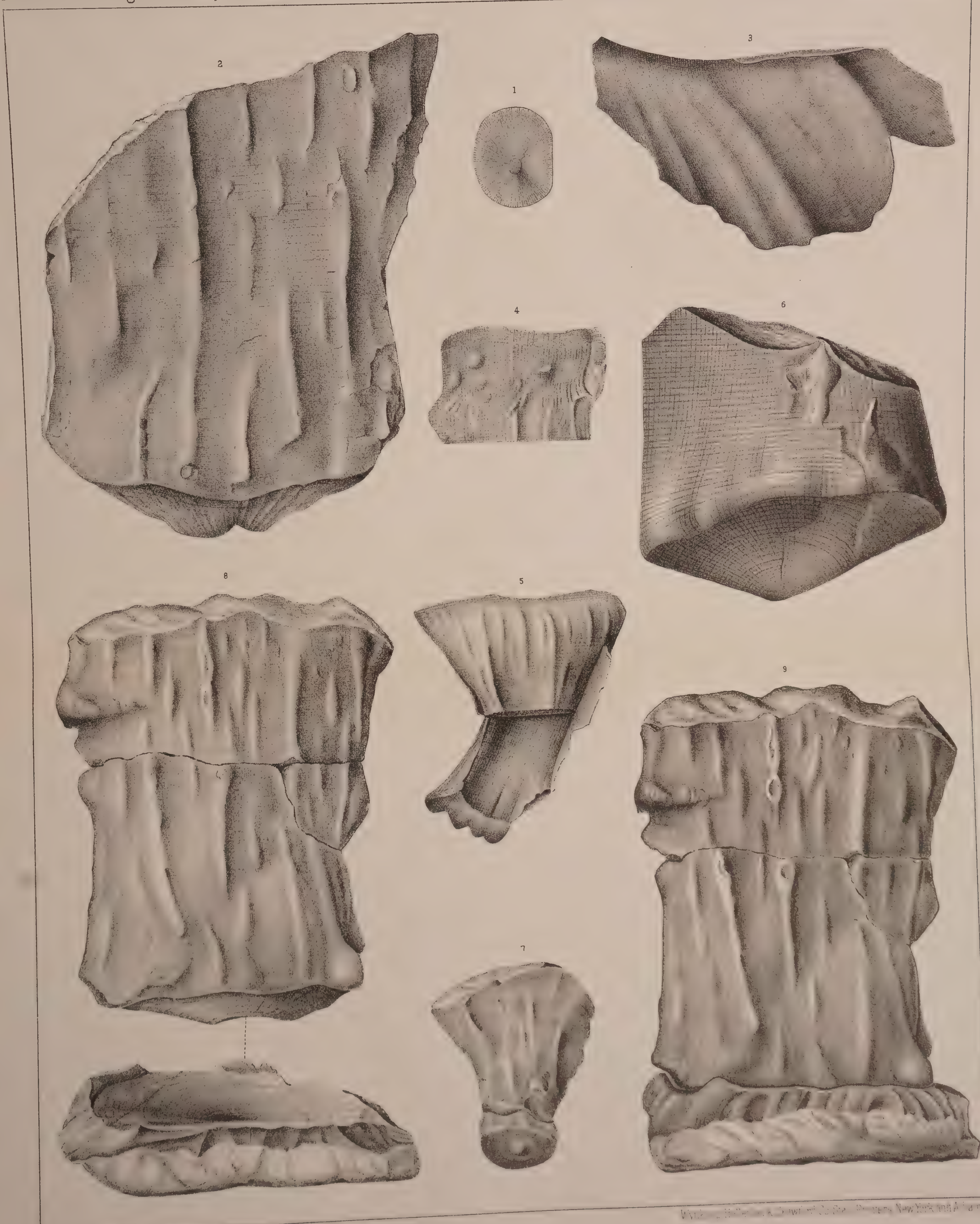

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PLATE LXVII.

PHRAGMODICTYA, Hall.

Page 364.

(See Plates LXIV, LXV, LXVI, LXVIII.)

PHRAGMODICTYA CATILLIFORMIS, Whitfield (sp.).

Page 365.

(See Plates LXIV, LXV, LXVI, LXVIII.)

Figures 1, 2. Opposite sides of a slender specimen, whose basal disc has an elongate apical scar of attachment.

Figure 3. A characteristic example of average dimensions showing the aperture and basal disc.

Figure 4. The apertural portion of a very large individual, showing the expanded cup, with the vertical ridges and scattered nodes of the surface.

Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.

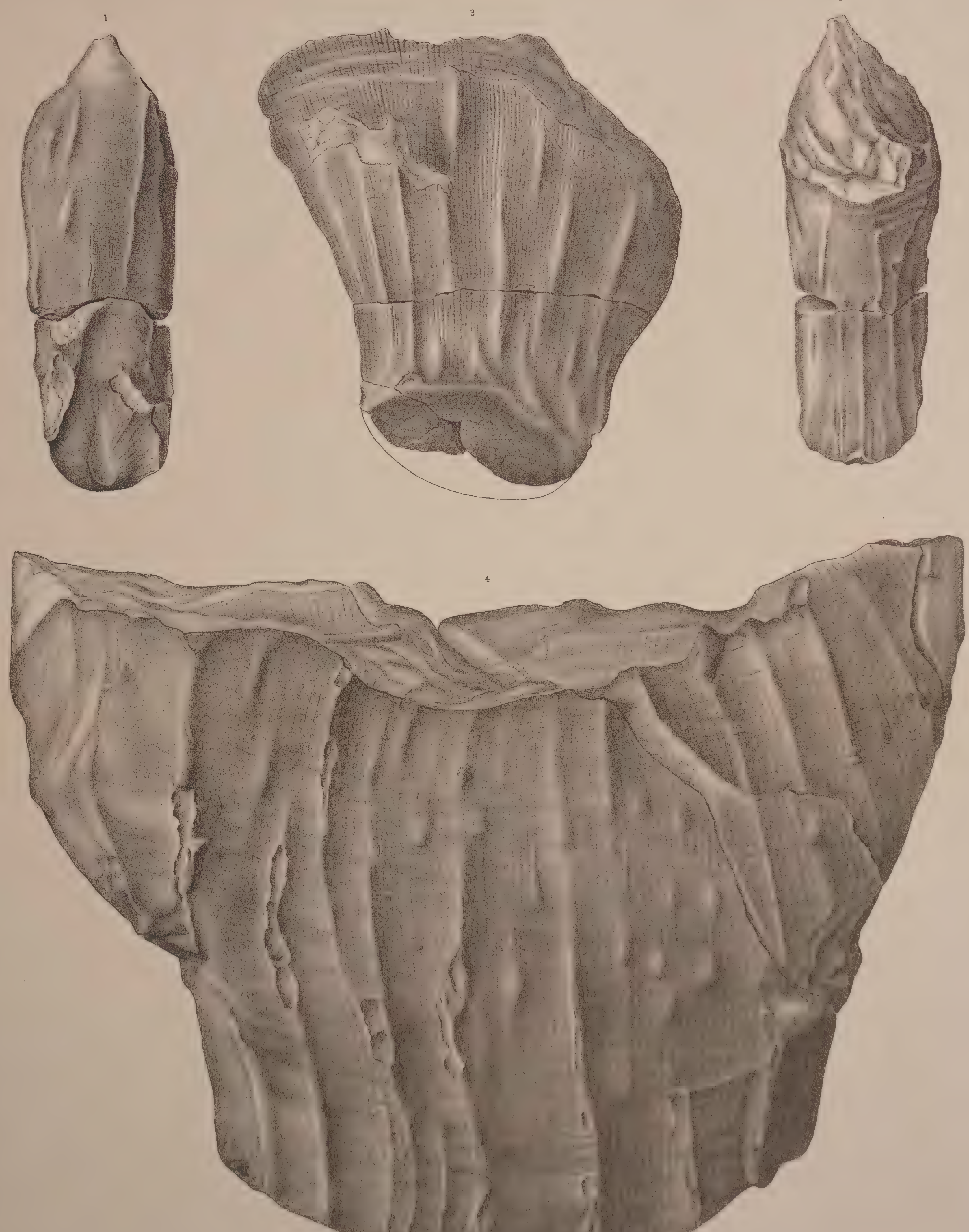

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PLATE LXVIII.

PHRAGMODICTYA, Hall.

Page 364.

(See Plates LXIV, LXV, LXVI, LXVII.)

PHRAGMODICTYA CATILLIFORMIS, Whitfield (sp.).

Page 365.

(See Plates LXIV, LXV, LXVI, LXVII.)

Figure 1. An average individual retaining the skeleton from the basal disc upward and preserving the usual configuration of the surface.

Figure 2. A small specimen, exposing the basal disc and part of the periloph.

Figure 3. A portion of a moderately large example showing the disc and the strong vertical surface ridges.

Figure 4. The concave or lower surface of the basal disc with the broad periloph attached.
Keokuk group. *Crawfordsville, Indiana.*

(?) PHRAGMODICTYA LINEATA, Hall.

Page 368.

Figure 5. The original specimen, which is a fragment of a smooth, slender subcylindrical cup, somewhat expanded about the lower end. It is probably not a species of PHRAGMODICTYA.
Keokuk group. *Crawfordsville, Indiana.*

CALATHOSPONGIA, gen. nov.

Page 347.

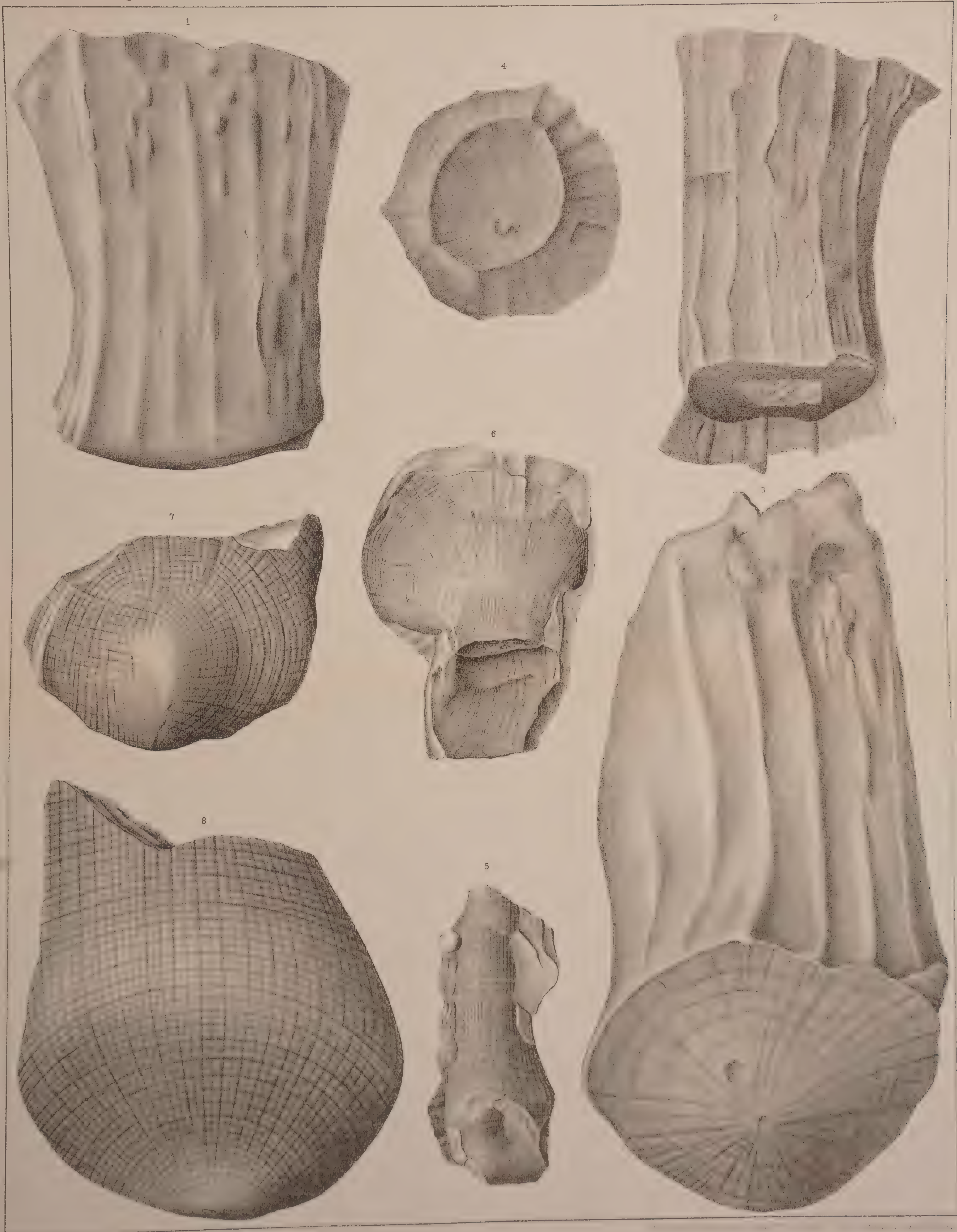
(See Plates XLVIII, XLIX, L, LI, LII, LVI, LVII, LX.)

CALATHOSPONGIA AMPHORINA, sp. nov.

Page 374.

Figure 6. A specimen with the flaring upper portion somewhat deflected but showing the general aspect of the sponge. The surface is smooth and the reticulum fine with prominent vertical spicular bundles.
Keokuk group. *Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.



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ACLŒODICTYA, gen. nov.

Page 369.

(See Plates LIV, LV, LX, LXI.)

ACLŒODICTYA MARSIPUS, sp. nov.

Page 370.

(See Plates LV, LX, LXI.)

Figures 7, 8. The basal parts of two specimens, showing the character of the reticulum and the broad curvature at the basal edge.
Keokuk group. *Indian Creek, Indiana.*

PLATE LXIX.

CLEODICTYA, Hall.

Page 355.

(See Plates LI and LXX.)

CLEODICTYA GLORIOSA. Hall.

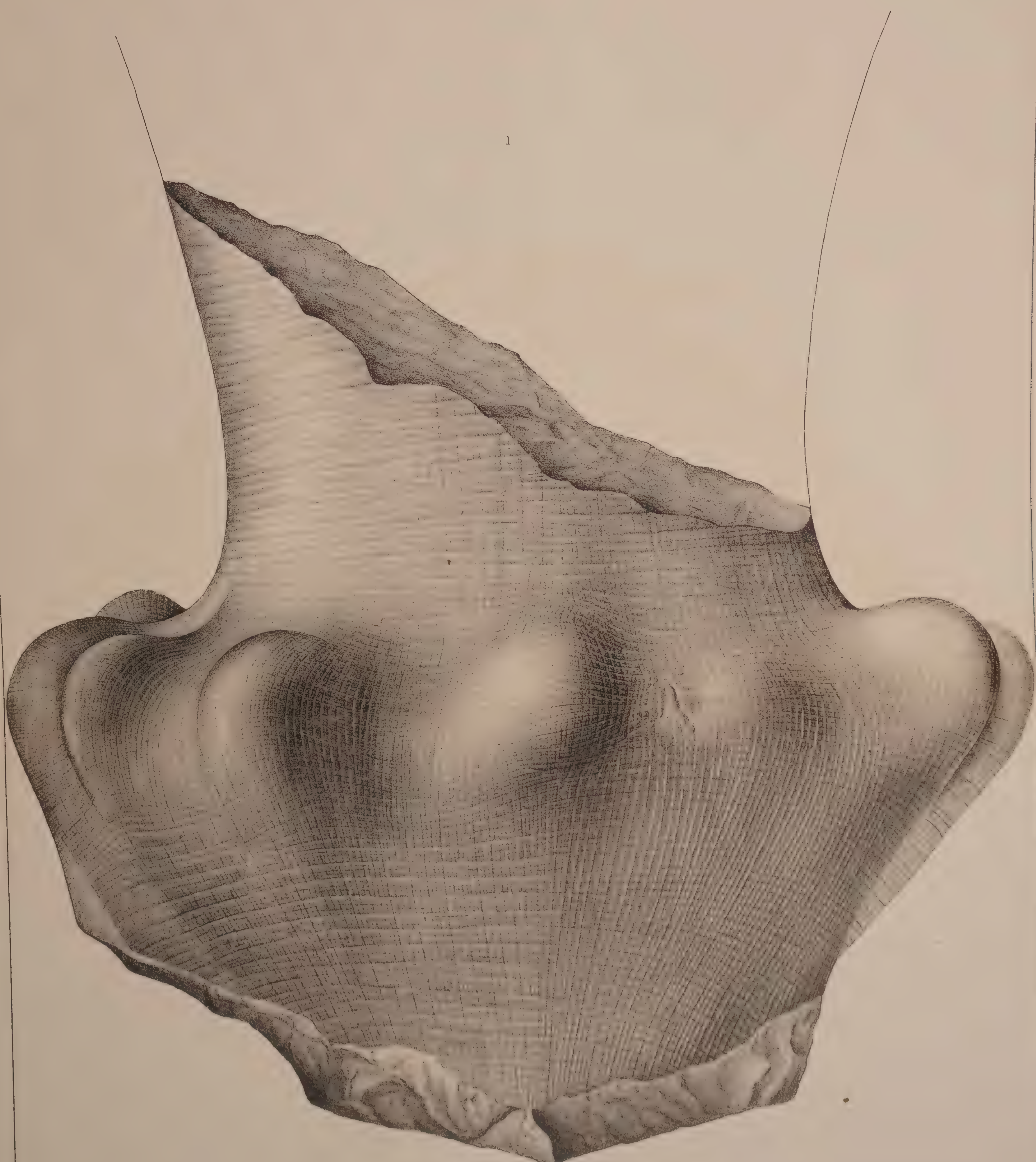
Page 375.

(See Plate LXX.)

Figure 1. Lateral view of the original specimen which shows the lower expansion with its broad obtuse nodes, and retains a part of the upper vase-shaped extension.

Keokuk group. *From the sandstone overlying the calcareous shales at Crawfordsville, Indiana.*

DICTYOSPONGIDÆ.



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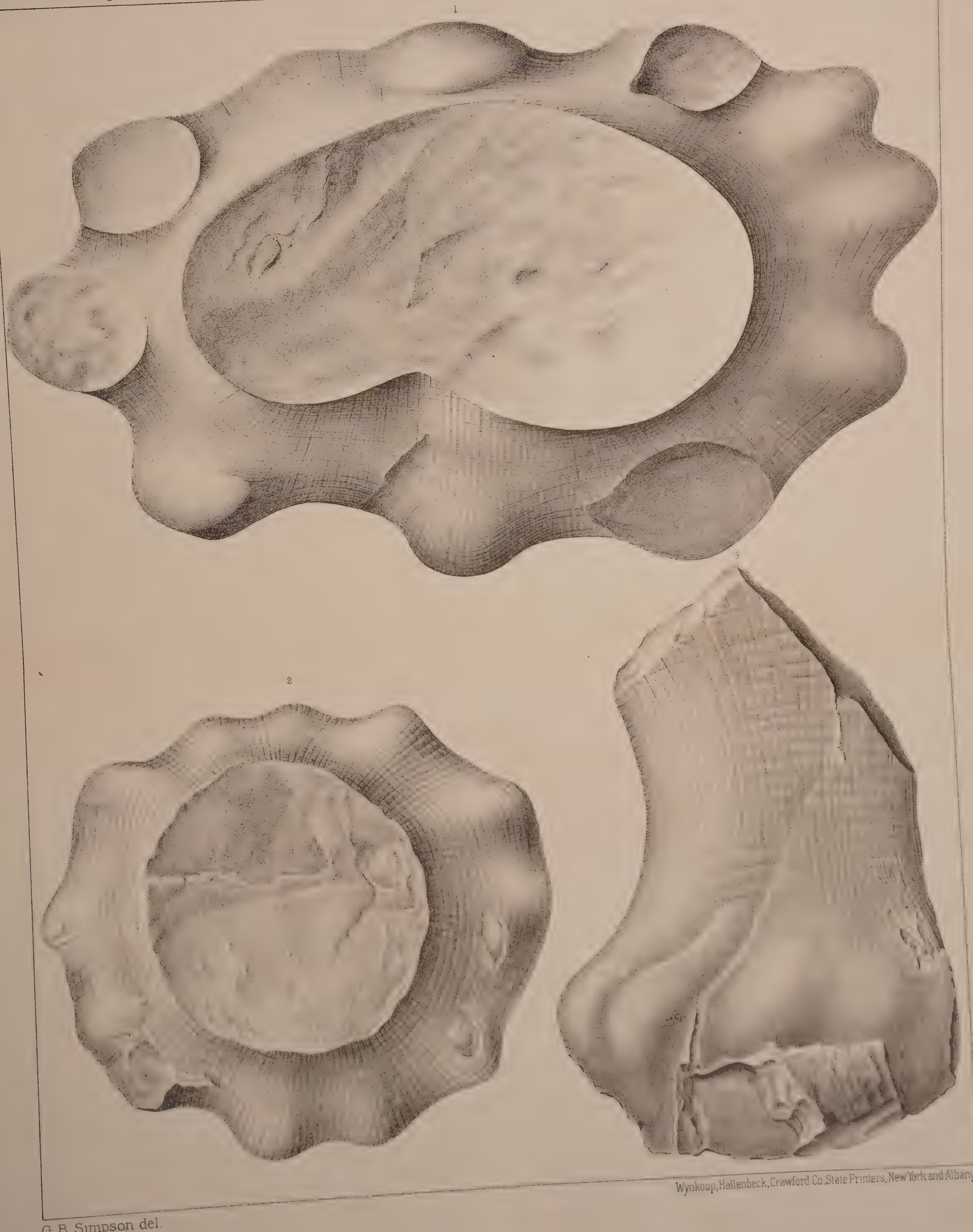
DICTYOSPONGIDÆ.



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DICTYOSPONGIDÆ.

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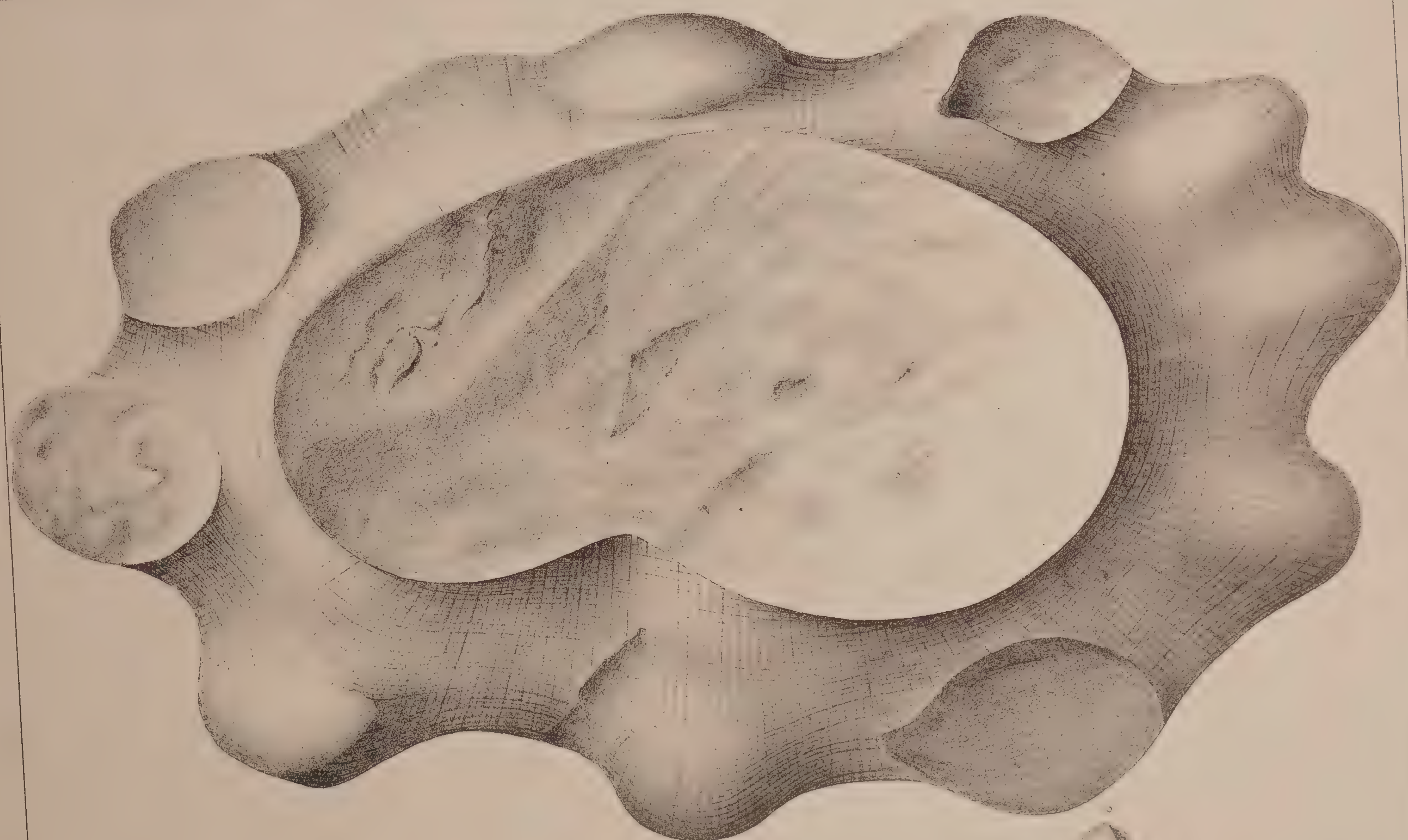

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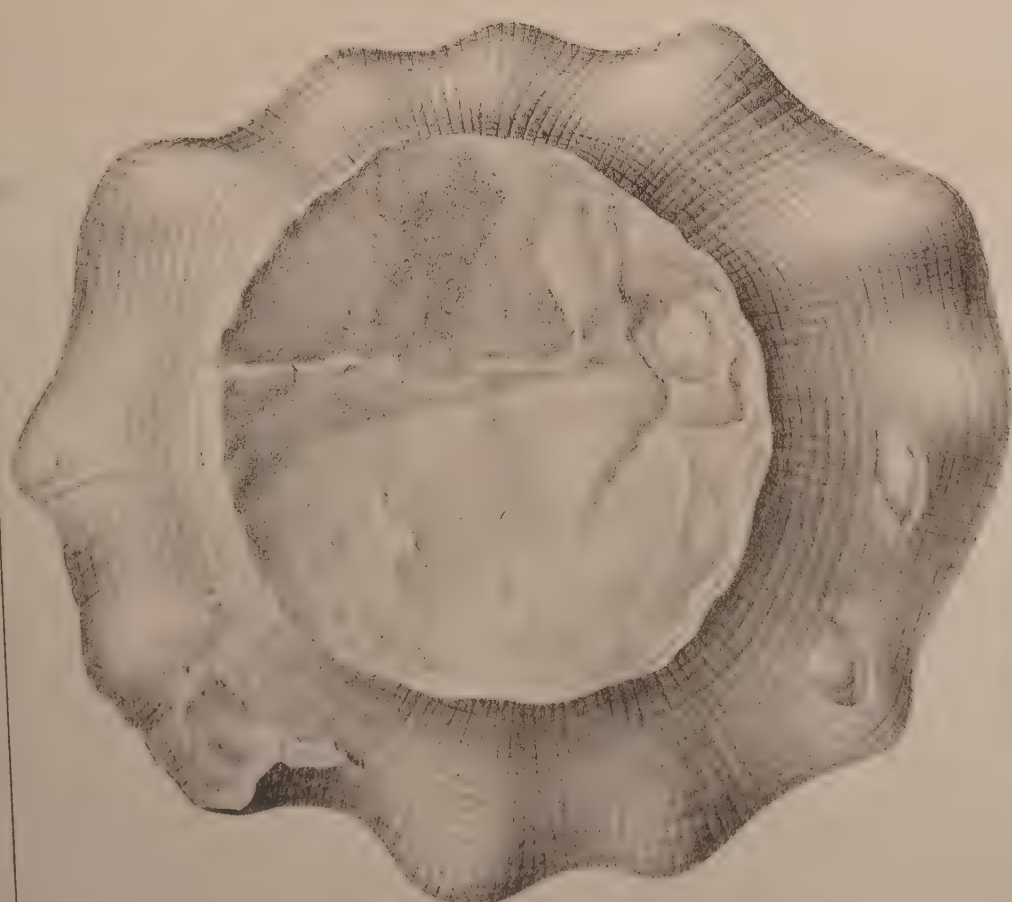

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To Personal Names.

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Numbers in black type indicate place of description.

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Numbers in black type indicate place of description.